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CLOUD BASED IP MULTIMEDIA SUBSYSTEM (IMS) ARCHITECTURE TO INTEGRATE VEHICULAR AD HOC NETWORK (VANET) AND IMS

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Ce mémoire intitulé:

CLOUD BASED IP MULTIMEDIA SUBSYSTEM (IMS) ARCHITECTURE TO INTEGRATE VEHICULAR AD HOC NETWORK (VANET) AND IMS

présenté par: RAHIMI Mahsima

en vue de l'obtention du diplôme de: Maîtrise ès Sciences Appliquées

a été dûment accepté par le jury d'examen constitué de :

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DEDICATION

I dedicate this thesis to my husband, Mehran, who has provided support and confidence during the challenges of graduate school and life. This work is also dedicated to my family for all their love and support.

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I would like to thank Professor Alejandro Quintero, my master's thesis advisor for his feedback in the area of my thesis and for his support, guidance and advice that helped me complete my thesis. I would like also to thank Nasrin Taherkhani, Éric Mayeul Fafolahan, Mohab Ali, Ryan Shaygan, Richard and all my past and present colleagues at LARIM for the enriching discussions we had. Finally, I would like to thank my dear husband Mehran. He has stood by me in all my projects and providing support and confidence.

RÉSUMÉ

Les réseaux Ad Hoc véhiculaires (VANET) représentent une technologie spéciale, dans la catégorie des réseaux ad hoc sans fils. Ils visent la sécurité routière, une plus grande efficacité et une meilleure organisation au sein des systèmes de transport. Ils favorisent l'avènement de nouvelles applications relatives à l'ingénierie, la gestion de trafic, la dissémination d'informations d'urgence pour éviter les situations critiques, le confort et le divertissement, ainsi que plusieurs autres «applications utilisateur».

Le sous-système multimédia IP (*IP Multimedia Subsystem*, IMS), a été standardisé par le projet «*Third Generation Partnership Project*» (3GPP) pour les réseaux hétérogènes avec un support de la qualité de service. Cette plateforme a été proposée dans le but d'offrir aux utilisateurs finaux des services multimédia tels que la voix, les données et la vidéo, la facturation ainsi que l'intégration des services tout-IP. Avec l'avènement de IMS, il est désirable d'offrir aux utilisateurs des réseaux véhiculaires (VANET), un accès aux services de ce sous-système. Cependant, les caractéristiques de ces réseaux posent des difficultés majeures pour le contrôle des performances des services IMS. Par ailleurs, le «réseau cœur » de IMS présente aussi des limitations telles que le contrôle centralisé, la faible efficacité et une faible évolutivité au niveau des équipements du réseau cœur en comparaison aux infrastructures de réseau utilisant le *Cloud Computing*. Le *Cloud Computing* est un nouveau paradigme des technologies de l'information, offrant des ressources extensibles dynamiquement, souvent au moyen de machines virtuelles et accessibles en tant que services sur Internet. La migration de l'IMS au sein du *Cloud* peut permettre d'améliorer les performances de l'infrastructure IMS. Ce projet propose une architecture novatrice d'intégration des réseaux VANET, IMS et le *Cloud Computing*.

ABSTRACT

Vehicular Ad Hoc network (VANET) is a special technology in wireless ad hoc networks. It can be used to provide road safety, efficiency and traffic organization in transportation system. Thus, new applications arise in several fields such as traffic engineering, traffic management, dissemination of emergency information in order to avoid critical situations, comfort, entertainment and other user applications.

IP multimedia Subsystem (IMS) is a subsystem, standardized with Third Generation Partnership Project (3GPP). The IMS supports heterogeneous networking with Quality-of-Service (QoS) policy. The goal of this platform is to integrate All-IP services and to provide final user with multimedia services such as voice, data and video with appropriate billing mechanisms. With the advent of the IP Multimedia Subsystem, it is desirable to provide VANET end-users with IMS services. However, characteristics of VANET cause major challenges to control the performance of IMS services. On the other hand, the traditional IMS core network faces a set of problems such as centralized control, low efficiency and poor scalability of core equipment, compared with the IT environment using Cloud Computing. Cloud Computing is an emerging paradigm in the field of information technology. In this new paradigm, dynamically scalable and often virtualized resources are provided as services over the Internet. The migration of IMS to cloud can improve its performance. This project proposes an innovative architecture in order to integrate VANET, IMS and Cloud Computing.

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3GPP	Third Generation Partnership
ACK	Acknowledgement
AODV	Ad-hoc On-demand Distance Vector
API	Application and Programming Interface
AU	Application Unit
CSCF	Call/Session Control Function
GW	Gateway
HSS	Home Subscriber Server
IaaS	Infrastructure as a Service
ICMP	Internet Control Messaging Protocol
ICT	Information and Communication Technologies
IMS	IP Multimedia Subsystems
ITS	Intelligent Transportation System
LUNAR	Lightweight Underlay Network Ad hoc Routing
MANET	Mobile Ad-hoc Network
MIH	Media Independent Handover
NIST	National Institute of Standards and Technology
OBU	On Board Unit
PaaS	Platform as a Service
PDA	Personal Digital Assistant

PIDF	Presence Information Data Format ()
PMU	Presence Manage Unit
PS	Presence Server
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RSU	Road Side Unit
SaaS	Software as a Service
SIP	Session Initiation Protocol
UE	User Equipment
VANET	Vehicular Ad-hoc Network
Wi-Fi	Wireless Fidelity
I-CSCF	Interrogation Call Session Control Function
S-CSCF	Serving Call Session Control Function
P-CSCF	Proxy Call Session Control Function
LTE	Long- Term Evolution
AS	Application Server

CHAPTER 1 INTRODUCTION

Intelligent Transport Systems and Services (ITS) deploy Information and Communication Technologies (ICT) in order to improve road safety, to provide drivers and passengers with information related to traffic management and to offer entertainment services. The main components of ITS architecture are roadside infrastructures and vehicles, which communicate via wireless technology. Roadside infrastructures and vehicles create a new challenging network environment named Vehicular Ad hoc Networks (VANETs)[1].

VANET is designed to improve roadway safety and traffic efficiency. Then, It allows decreasing road dangers for drivers, passengers and pedestrians. VANET supports safety applications such as emergency breaking, traffic jam detection and forward collision warning. User applications are also supported and provide road users with value-added services (e.g. games, chat-rooms and vehicle data sharing).

VANET is characterized by high mobility, high rate of topology changes and high variability in node density. Thus, providing all vehicular terminals with the Internet services raises major challenges.

Moreover, with the growth of wireless and Internet technologies, various applications such as real-time video, multimedia streaming and interactive games are widely developed and deployed. IP Multimedia Subsystems (IMS) is a control architecture on the top of the IP layer whose goal is to provide multimedia services dependent the Quality of Service (QoS), integrated services and fair billing scheme throughout standard interfaces. IMS is a subsystem, which has been standardized with Third Generation Partnership Project (3GPP)[2]. It supports heterogeneous networking with Quality-of-Service (QoS) policy. The goal of this platform is to provide final user with multimedia services such as voice, data and video. IMS is based on three main characteristics:

1. The provision of the Quality of Service (QoS) to real-sessions. It means that the operator is capable to control the service a user can get.
2. The fair billing scheme to multimedia service is permitted. This is an important factor that can be considered since sessions can be created among users or services located in different networks.

3. Services integration throughout standard interfaces. IMS enables services such as instant messaging, conferencing and third party call to cellular user through standard interfaces.

Cloud Computing is an emerging paradigm in the field of information technology. In fact it is a new paradigm in IT technology including dynamically scalable and often virtualized resources, which are provided as services over the Internet[3]. Cloud Computing enables ubiquitous, convenient, on-demand access to shared pool of configurable computing resources that can rapidly provisioned and released with minimal management effort or service provider interaction. We can follow the characteristics of Cloud Computing below:

1. On-demand self-service: A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service's provider.

2. Broad network access: Capabilities are available over the network and accessible through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).

3. Resource pooling: The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence such as the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, network bandwidth, and virtual machines.

4. Rapid elasticity: Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out, and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

5. Measured Service: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

With regards to these characteristics, it is desirable for road users in VANET to utilize IMS services based on Cloud Computing. Integrating these three evolving technologies gains more interest in the research community in recent years because of great advantages and services they provide. This project focuses on presenting the appropriate architecture to provide VANETs with multimedia service through Cloud based IMS. We present promising mobile gateway in VANETs that provides VANETs with IMS services in heterogeneous networks based on Cloud Computing.

1.1 Definition and basic concept

This section includes background information pertinent to this project. This part can help the reader to have better understanding of primitive concepts of VANET, IMS and Cloud Computing.

Firstly a brief survey of VANETs is presented. Later on, the IMS core architecture is introduced and is explained in further detail. Finally, the features of cloud computing will be discussed in detail.

1.1.1 Vehicular Ad Hoc Networks (VANETs)

VANET is the technology of building a robust Ad-hoc network between mobile vehicles, and, moreover, between mobile vehicles and roadside units. As shown in Figure 1.1, there are two types of nodes in VANETs; mobile nodes as On Board Units (OBUs) and static nodes as Road Side Units (RSUs)[4]. An OBU resembles the mobile network module and a central processing unit for on-board sensors and warning devices. The RSUs can be mounted in centralized locations such as intersections, parking lots or gas stations. They can play a significant role in many applications such as a gate to the Internet.

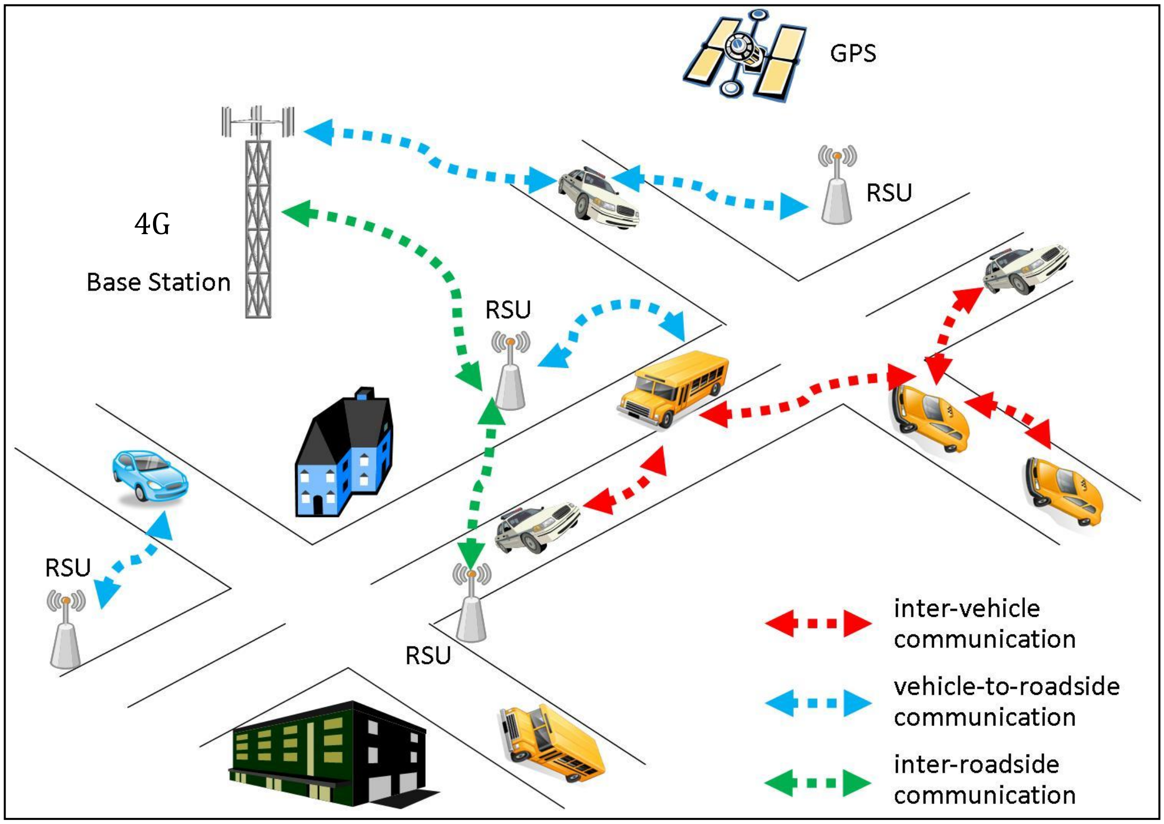

Figure 1.1.VANETS Structure [5]

In order to provide safety and comfort to the road users, VANET is one of the influencing areas for the improvement of Intelligent Transportation System (ITS). It assists vehicle drivers to communicate and to coordinate among themselves according to the avoidance of critical situation through Vehicle-to-Vehicle communication. For instance, road side accidents, traffic jams, speed control, free passage of emergency vehicles and unseen obstacles are several application cases. Besides safety applications, VANET also provides comfort applications to the road users. For example, weather information, mobile e-commerce, Internet access and other multimedia applications.

1.1.2 IP Multimedia subsystem (IMS)

IMS provides ubiquitous access to Internet services everywhere using cellular networks. As defined by Camarillo in [2], “Third generation (3G) networks aim to merge two of the most successful paradigms in communications: cellular networks and Internet”.

The advantage of using IMS is the provision of service integration through a standard architecture, the consideration of QoS and a differential charging scheme. Firstly, integration of services allows operators and users to access different services in the same way by using standard interfaces. It also allows operators to build and provide new services combining or integrating existing ones. Additionally, IMS deals with the synchronization in session establishment considering QoS provision, which improves considerably real-time communications, for example in multimedia sessions. Finally, IMS charging is determined by the operator and depends on the services used by the user and not by the bytes he/she transfers as it is done with today’s architecture.

IMS is an overlay control layer on the top of an IP layer. As shown in Figure 1.2, four logical layers are defined as part of the IMS architecture: device layer, transport layer, control layer and service layer. The device layer represents the different networks that could access IMS when connecting to an IP network. The transport layer is responsible for initiating and terminating SIP sessions and providing conversion of data. In addition to the IP network, the transport layer allows IMS devices to make and to receive calls to and from the Public Switched Telephone Network (PSTN).

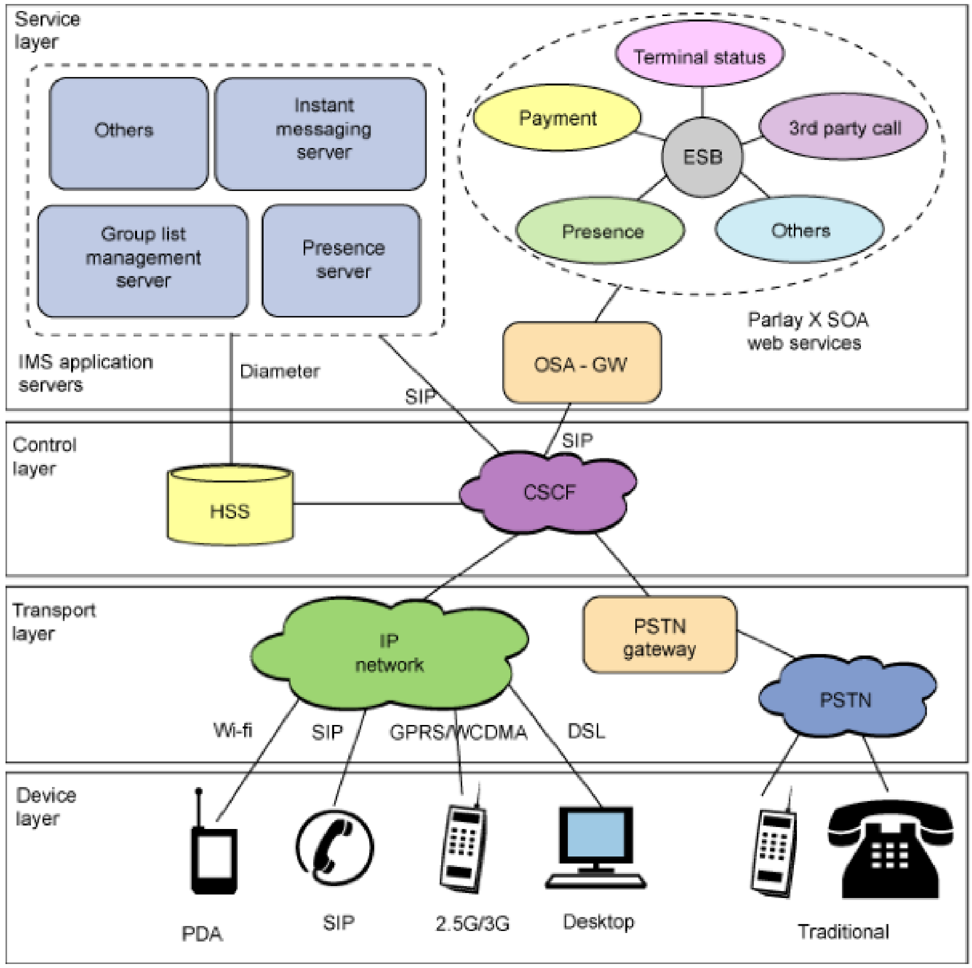

Figure 1.2. IMS Architecture[6]

The control layer is composed by the CSCF (Call/Session Control Function) and the HSS (Home Subscriber Server), which are essential entities in the IMS architecture. CSCF refers to a set of SIP servers (i.e. Proxy-CSCF, I-CSCF and S-CSCF) that process SIP signalling. And the HSS is a central repository that contains user-related information

Finally, on top of the IMS network architecture is the service layer. At this layer, application servers are found. An application server is a SIP entity that hosts and executes services. One of the services already being provided at this layer is the Presence Service that will be further explained in chapter 2.

1.1.3 Cloud Computing

Cloud Computing is an emerging paradigm in Information Technology industry. National Institute of Standards and Technology (NIST) defines Cloud Computing as following[7]: "Cloud Computing is a model for enabling convenient, on-demand request network access to shared pool of configurable computing resources (e.g. networks, servers, storage and servers) that can be rapidly provisioned and released with minimal management effort or service provider interaction."

The features of Cloud Computing include on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service. (See section 2.3)

Figure 1.3 illustrates the service model of Cloud Computing. This model consists of three layers including Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Software as a Service (SaaS) or cloud application service delivers software over the Internet. It eliminates the need to install the application on the customer's own computers, simplifies its maintenance and support [8].

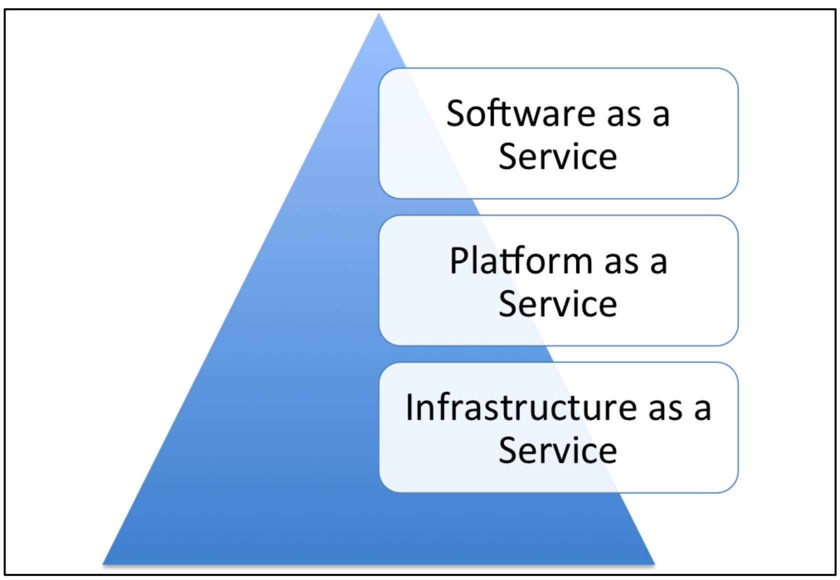

Figure 1.3.Cloud Computing Architecture

Platform as a Service (PaaS) or cloud platform service delivers a computing platform as a service. It facilitates deployment of applications without the purchase cost and the complexity of managing the underlying hardware and software layers. It hides the complexity and details of infrastructure from users by API (Application and Programming Interface), a simple graphical interface[8].

Infrastructure as a Service (IaaS) or cloud infrastructure service delivers computer infrastructure as a service. Clients don't need to purchase software; network equipment or data center space and they buy those resources as a fully outsourced service[8].

1.2 Aspects of the problems

Integrating Cloud based IMS and VANETs will open the door to wide range of new multimedia services. Basically it allows the provisioning of new and optimized services with efficient QoS.

To further explain the problem, we could analyze the scenario for the road user who wants to use IP-based multimedia services in his/her car during the trip. For instance, it is possible that road user wants to send instant message to another car or using real-time multimedia services. Because of the characteristics of ad hoc network, providing the real-time services with acceptable QoS for VANET raises a lot of challenges. The current architecture, which uses Road Side Unit (RSU) and centralized architecture, cannot provide road users in VANET with stable, high Internet access and multimedia services. The high-speed nodes in VANETs move in and out of range of RSUs; therefore, the Internet connectivity is not stable and quality of service goes down because of frequency interruptions during handovers between RSUs.

The IMS, which is defined by 3GPP, supports high-speed IP-based data, voice and multimedia services with controlling the QoS. This traditional IMS architecture core network faces the set of problems such as centralized control, low efficiency and poor scalability of core equipment, compared with the IT environment using Cloud Computing.

On the other hand, with advent of Cloud Computing, a lot of services suppliers over the Internet, migrates to Cloud Computing to benefit from the main features of Cloud Computing. In this trend, IMS is not excluded.

Therefore, lack of stable Internet connectivity in VANET to receive multimedia service and inefficient centralized IMS architecture creates major risks in QoS. Up to our knowledge, there is not the architecture to integrate VANET, IMS and Cloud Computing to provide road users in VANET with IMS services.

1.3 Research Objectives

Our main goal is to design and develop an architecture to integrate VANET, IMS and Cloud Computing with appropriate mobile gateway as a middleware. More precisely, this project has the following goals:

1. Propose appropriate mobile gateway located in vehicles in order to meet requirements of IMS, VANETs and Cloud Computing integration;
2. Develop a prototype of the middleware as a proof of concept;
3. Validate the proposed middleware by evaluating and comparing the output results.

1.4 Outline

The rest of this dissertation is organized as follows. The Chapter II presents the state of the art according to the integration of VANET with the Internet services and, more especially, with IMS. In chapter III the proposed architecture is exposed in details. The Chapter IV is devoted to the performance analysis of the proposed architecture. The interaction between VANET and Cloud-Based IMS is also simulated in this chapter. Finally, we conduct the conclusion and the future works.

CHAPTER 2 STATE OF THE ART

This chapter presents the state of the art from different technologies and integrations conceived in this project. In the first section, we will explain VANETs and consider different aspects of this network. Secondly, we will explain and describe IMS architecture in detail. Thereafter, we will present a brief survey on the integrations that have been done between VANETs and IMS framework. Then, in fourth section, we will introduce the IEEE 802.21 standard framework and make clear how this technology can meet the requirements. Later on, the Cloud Computer features along with Cloud based IMS architecture will be presented. Finally, benefits and weakness of the current overlay solution for system integration are presented.

2.1 Vehicular Ad-hoc Network (VANET)

As regards, VANET is designed to improve roadway safety and traffic efficiency, thus it can be considered an important issue for academic and industrial researches[9]. In this section, we present basic concepts on these networks.

2.1.1 Characteristics of VANET

VANET are a subgroup of Mobile Ad hoc Network (MANET). So, VANET inherits many of characteristics of MANET. Furthermore, VANET has some additional specific features including low cost, flexibility, fault tolerance, creating new applications for remote area[10, 11]. Some of these unique characteristics are discussed in the following:

1. High dynamic topology: Topology changes have high frequency in VANETs because there are variable parameters during the trips of the vehicles such as speed of movement, connection lifetime, choice of path and multi-hop organization. In the other word, these variable factors, which are the unique features in VANET, cause dynamic topology in VANET[10].

2. Frequency disconnected networks: In order to decrease the effect of fading and to perform seamless connectivity, the time between link disconnection and choosing another link connection should be too short. However, in low-density situation, the problem of disconnection increases. This problem could be solved by using roadsides and relay nodes[1].

3. Mobility modeling and operating environment: In order to obtain efficient connectivity, it is necessary to know the position of nodes and their movement directions to predict the next hop and prevent the link disconnection. This is due to the fact that the VANETs mobility model is limited by plan of roadways. In addition, changing the mobility model (highways or urban environments) can effect on designing the VANET algorithms. Highway mobility model is simple due to one-dimension model. Whereas in urban model, some features like street structure, high node density, two dimension roads, obstacles and interferences via tall buildings and trees in city, must be considered. These features cause to have different and complex design for VANET in urban environments [10, 11].

4. Partitioned networks: Dynamic nature of road traffic creates the gaps between the vehicles' communications and generates isolated node clusters in the roadways[10].

5.Infinite energy supply: Rechargeable batteries can provide road users with sufficient energy and solve the energy constraint problem in VANET[9].

2.1.2 Applications of VANETs

The applications in VANETs are classified in two main categories including safety applications and non-safety applications or user applications[1].

Safety applications provide safety environment in VANET. These applications try to decrease the accident and traffic collisions in roadways, which are important in situations such as accidents, intersections and road congestion. According to high speed of vehicles in roads, drivers cannot react correctly in hazard situations. If the drivers are informed about an accident that can be occurred in front of them, the safety applications can be used to warn vehicles. When vehicles receive some emergency messages from safety applications, they can reduce the speed before they approached to the accident, thus it is possible to prevent another accident.

Another group of VANETs' applications are non-safety (user) applications. These kinds of applications are used for providing information about traffic jam, comfort driving and route optimizing.

According to daily requirement of the Internet for peoples who travels with vehicles, non-safety application of VANET must provide seamlessly the Internet connectivity for drivers and passengers. Also peer-to-peer applications have been employed for file sharing or playing game between vehicular users [4, 10].

2.1.3 Architecture of VANET

System architecture of VANETs composed of various components, which are depicted in figure 2.1. Three district domains can be considered for VANETs architecture. In-vehicle domain consists of On-Board Unit (OBU); each vehicle is equipped with this unit. The OBU provides short-range wireless communication for safety and non-safety communications. The ad hoc domain is formed of OBUs and Road-side Units (RSUs). One mobile ad hoc network can be considered between OBUs that makes inter-vehicle communications for peer-to-peer and safety broadcasting. OBUs communications are one hop or multi-hop regarding to communication generator application.

Finally, infrastructure domain consists of RSU and Hotspots (HS) that is used for accessing to safety and non-safety applications. RSUs provide the Internet access, while HS is considered for less controlled environments. In addition, if the Internet access cannot provide by RSUs or HSs, thus OBUs can use integrated cellular network capabilities (e.g. GSM, GPRS, UMTS, HSDPA, WiMAX, 4G) for the Internet usage.

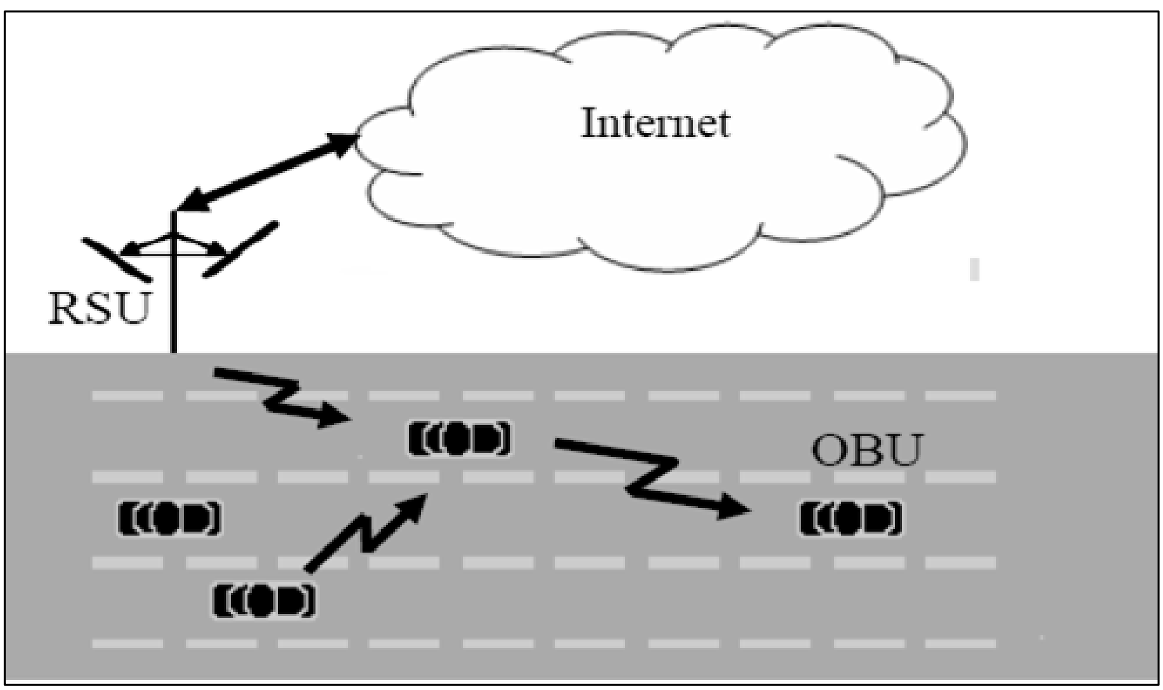

Figure 2.1.VANET system Architecture [12]

2.2 IP Multimedia Subsystem (IMS)

As mentioned before, IMS is the key element in 3G architecture. Although all the Internet services are usable and available for 3G users via packet-switched domain, we need IMS in order to ensure Quality-of-Service, manage charging and integrate different services. Therefore, the following requirements should be considered in IMS framework[2]:

- Support for establishing IP Multimedia Sessions, which means to support multimedia sessions over packet-switched network
- A mechanism to support Quality-of-Service.
- Support interworking with the other networks, which means to be able to support heterogeneous network.
- Support for roaming
- A service control to charging mechanism
- Support for secure communication

In this part, we explain how the architecture and IP-based protocols of this subsystem support and provide above requirements. IMS is an overlay control layer above the IP layer[13].

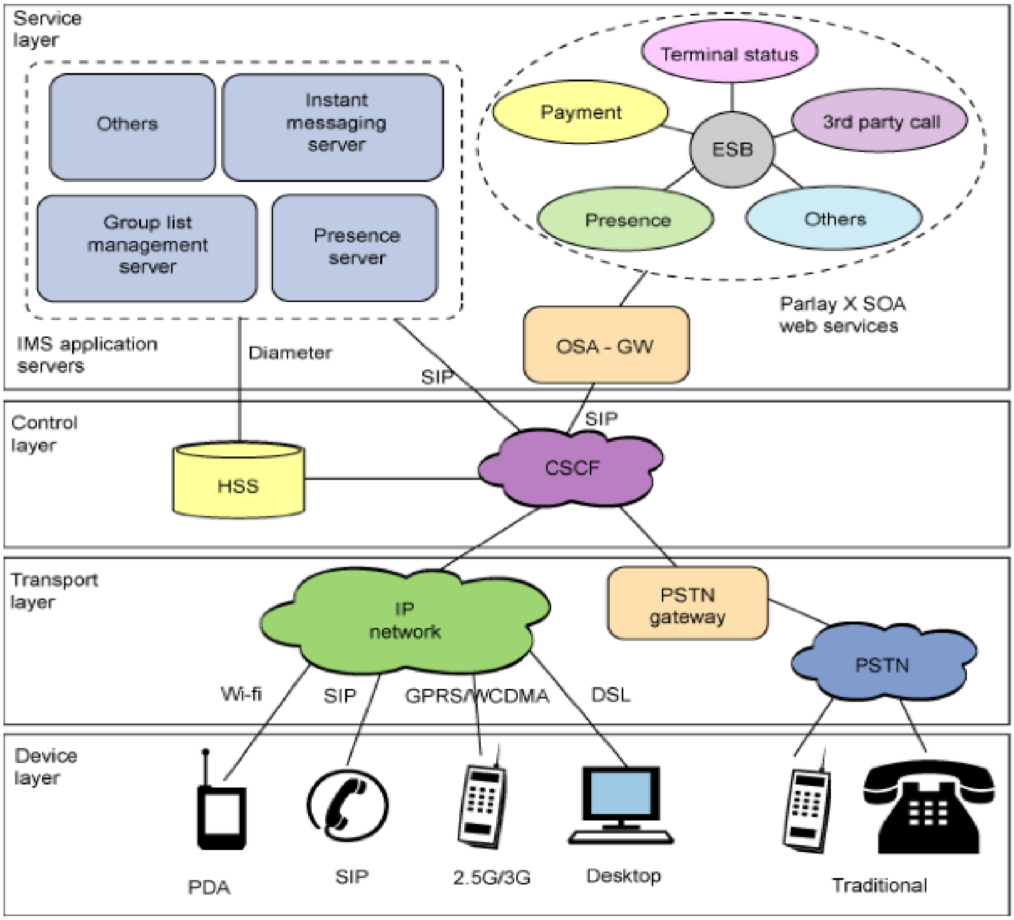

Figure 2.2.Multimedia Subsystem (IMS) CORE [6]

As shown in Figure 2.2, there are four layers in architecture of IMS. The device layer includes all the mobile and fix devices. The transport layer is responsible for initiating and terminating SIP session and providing conversion of data. In the control layer Call/Session Control Function (CSCE) and Home Subscriber Server (HSS) are the essential nodes in IMS Architecture. CSCF are composed of the set of SIP servers processing SIP signalling. On top of the control layer, we can see the service layer. This layer presents all the services, which are provided by the IMS.

IMS core network consists of nodes, which are classified in three groups, including databases, SIP servers and Application servers. Figure 2.3 shows the relation among these three groups.

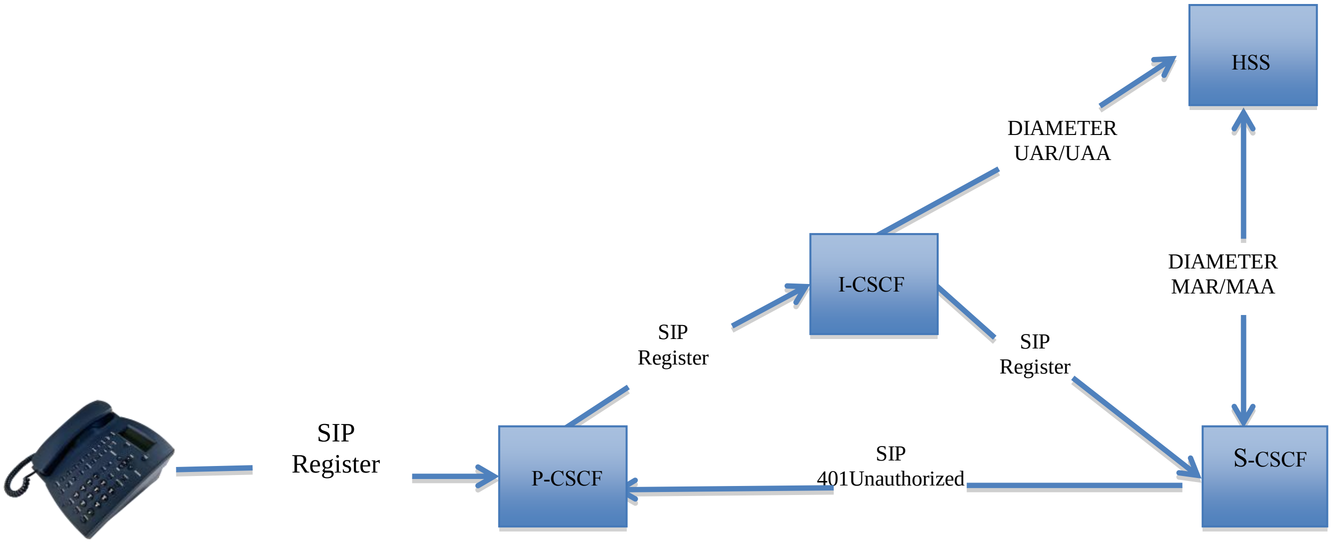

Figure 2.3.The relation among SIP servers and HSS

In the first group, the Home Subscriber Server (HSS) and the Subscription Locator Function (SLF) are two databases in IMS architecture. HSS and SLF are using as central repository for user-related information and mapping user address respectively. The former is the master database for given user. It contains the user identities, registration information, access parameters and the other subscription-related information to support network entities and handle calls/sessions.

The later one is necessary if the network has more than on HSS. In fact, SLF maps address of users to HSS. It gets the user, address as input and then it finds which HSS contains the relevant information about that user.

The second group can be considered as SIP servers. These SIP servers, collectively called Call Session Control Functions (CSCFs), are essential nodes in IMS. They play important rule to process SIP signalling packet in IMS. Each individual CSCF node has three important entities including P-CSCF, I-CSCF and S-CSCF.

1. Proxy-CSCF (P-CSCF): It is the first point of contact with IMS terminal. All the requests sent from IMS user traverse this entity. THIS sip proxy forwards SIP requests and responses in the appropriate direction. Before registration, the P-CSCF is assigned to IMS terminal and it does not change during the call session. The user authentication,

compression and decompression of SIP messages, IPSec or TLS association and interaction with Policy and Charging Rules are all the functions carried out in P-CSCF entity. Depends on underlying packet network, this entity usually is located either in home network or visited network.

2. Serving –CSCE (S-CSCF): When a subscriber enters the network, subscriber has the user location (e.g., the IP address of the terminal the user is logged onto) and the user' SIP address (also known as Public User Identity). The main rule of S-CSCF is to bind these two addresses in order to session control. This entity is enabling to inspects SIP message, forbid unauthorized operations, provide SIP routing service. Because of interfaces between S-CSCF and HSS, user profile in HSS including set of triggers causes SIP messages to be routed to appropriate application server.
3. Interrogating-CSCF (I-CSCF): Interrogates HSS in order to obtain the address of relevant S-CSCF because each IMS core can have several S_CSCF. This entity also has interface with Application server in order to address the requests for services.

Application Servers are located in third and last group. It provides value-added multimedia services. This entity has interfaces with the other SIP sever as mentioned above. This entity process incoming SIP session, generate SIP request and send accounting information to the charging function.

2.2.1 IMS and Protocols

The protocols play important role to control user session in IMS. All these protocols are based on IP. One, which is proposed by IETF, is SIP (Session Initiation Protocol) protocol. This protocol is chosen by 3GPP in order to establish and manage multimedia session over IP Networks. SIP inherits the most of its characteristic from HTTP and SMTP, which are the most successful protocols in the Internet; therefore, like HTTP and SMTP, this protocol is text-based. This means that it is easier to debug, extend and build new services.

As mentioned above, like HTTP, SIP is based on request/response transaction and each request invokes particular procedure on SIP servers. As shown in Figure 2.4, each SIP messages (INVITE, SUBSCRIBE…) from the user agent is forwarded to P-CSCF.

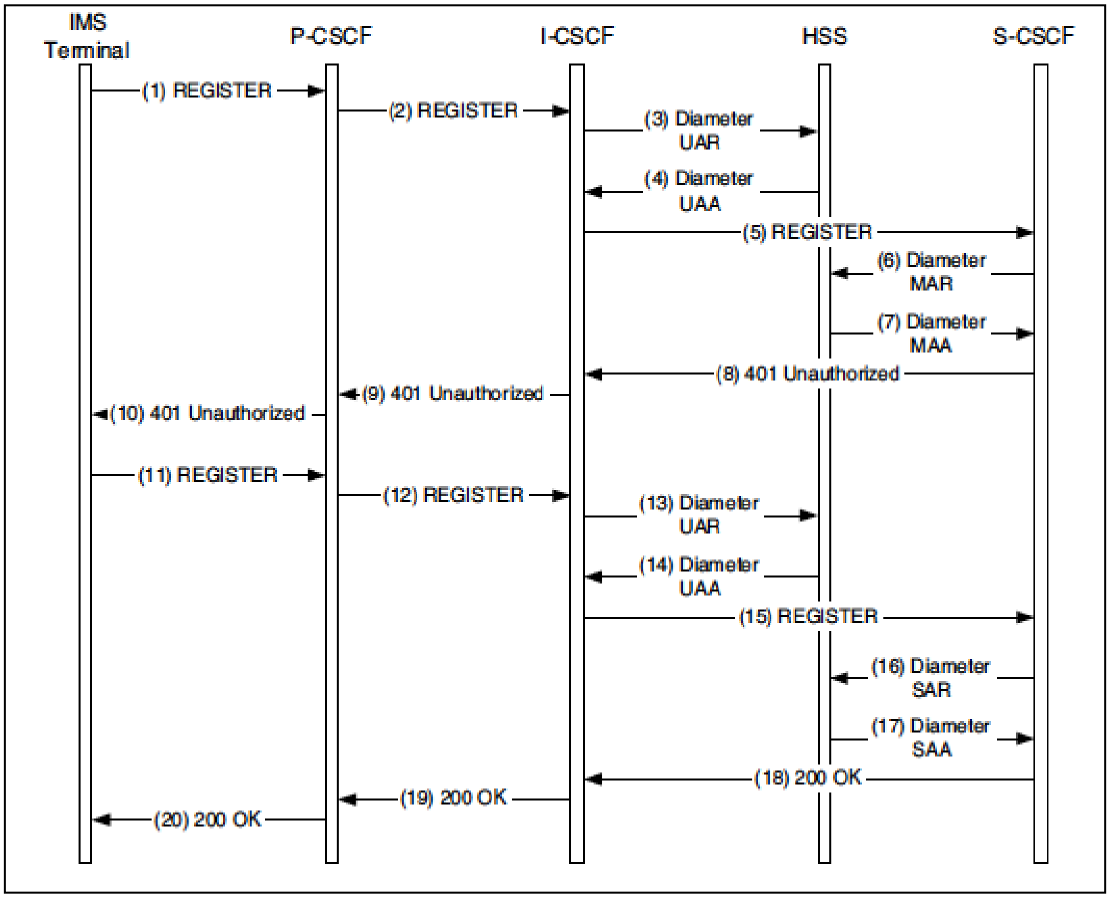

Figure 2.4. Registration at IMS level[2]

The SIP register messages are always sent to the I-CSCF. This entity can query HSS in order to find relevant S-CSCF to forward the request to. Then, S-CSCF manages the user after successful authentication by HSS. According to user profile, S-CSCF forwards the request of the user agent to application server depending on the different service subscribed by the user.

The mobile IMS terminal, which is in our case the mobile node in VANETs, must be re-registered each time it changes its IP address or change access point. For this purpose, it should re-invite the correspondent node.

2.2.2 Presence Framework of IMS

The presence service of IMS allows an entity to share some information about its situation, position, reachability, availability, and willingness of communication with another entities. It can provide an extensive amount of information about a person to a set of interested users. Even more, services are able to read and analyze this information to provide further services.

The presence framework defines four roles:

Presence Entity – “Presentity”. It refers to the entity providing presence information (e.g. status, capabilities and location). It has several Presence User Agents (PUAs), which provide this information to the Presence Service. Each PUA can collect different pieces of information.

Presence Agent (PA) - It gathers information sent by the PUAs and obtains an idea of the user’s presence.

Presence Server - It is a functional entity that acts as either a PA, as proxy server for SUBSCRIBE requests or as both. In IMS, this entity is represented as an Application Server that acts as a PA.

Watcher - It refers the user that requests presence information from presentity.

It is built on top of the SIP event notification framework; which is based in SUBSCRIBE/NOTIFY requests. A watcher subscribes to receive information from a presentity for a period of time or for requesting some specific information. The presentity’s PA will send the information to the watchers using a SIP NOTIFY request. Presence information is sent in the body of the messages and it is a XML document called PIDF. The PIDF carries the semantics of presence information between presence entities or roles. It is protocol independent and highly flexible; in fact some extensions have already been proposed to overcome some limitations.

Presence service is divided in three processes. The first one is the publication process where presentity’s PUAs send PIDF documents in a SIP PUBLISH message. IMS CSCFs forward the request to the Application Server that represents the Presence Server; which finally replies with an OK. The second process consists in the subscription of watchers. Through SIP SUBSCRIBE transaction, watchers request to receive information from presentity, watchers can be users or even other services. Once new information reaches the Presence Server a SIP NOTIFY is sent to subscribed users and services that can exploit the information[14].

2.2.3 IMS in Third Generation (3G) and Fourth Generation (4G)

The Third Generation (3G) or International Mobile Telecommunications-2000 (IMT-2000) is a generation for mobile phones and mobile communication. This technology permits to mobile phone users to use audio, graphics and video applications.3GPP (Third Generation Partnership project) and 3GPP2 (Third Generation Partnership Project 2) are two of standard bodies involved in IMT-2000.Both 3GPP and 3GPP 2 have standardized their own IMS. The 3GPP IMS and

3GPP2 IMS use Internet protocol and collaborate with IETF (Internet Engineering Task Force)[2]. In Figure 2.5, we can have an overview of the IMS architecture, which is provided by 3GPP.

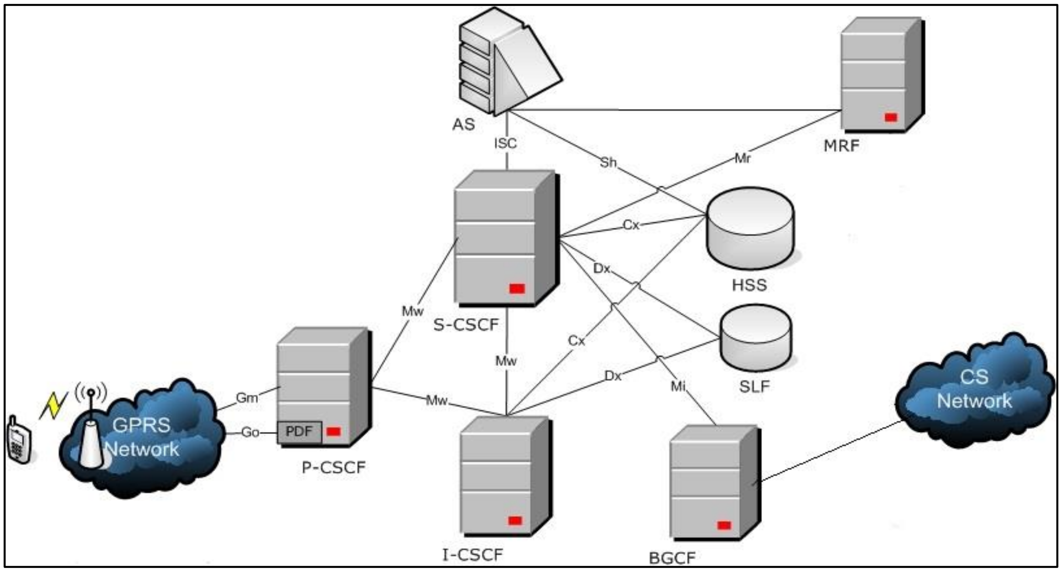

Figure 2.5 .3GPP IMS architecture overview

In order to eliminate the weaknesses of 3G of mobile networks, The Fourth Generation (4G) of mobile network was introduced. This generation provides fast access to services, minimized latency and round trip delay, network architecture to match with high bit rate radio and low cost. Figure 2.6 illustrates the architecture of IMS in 4G. As we can see in figure 2.6, the 4G networks splits in three parts including Access Network and Transport Network, Evolved Packet Core (EPC) and Applications.

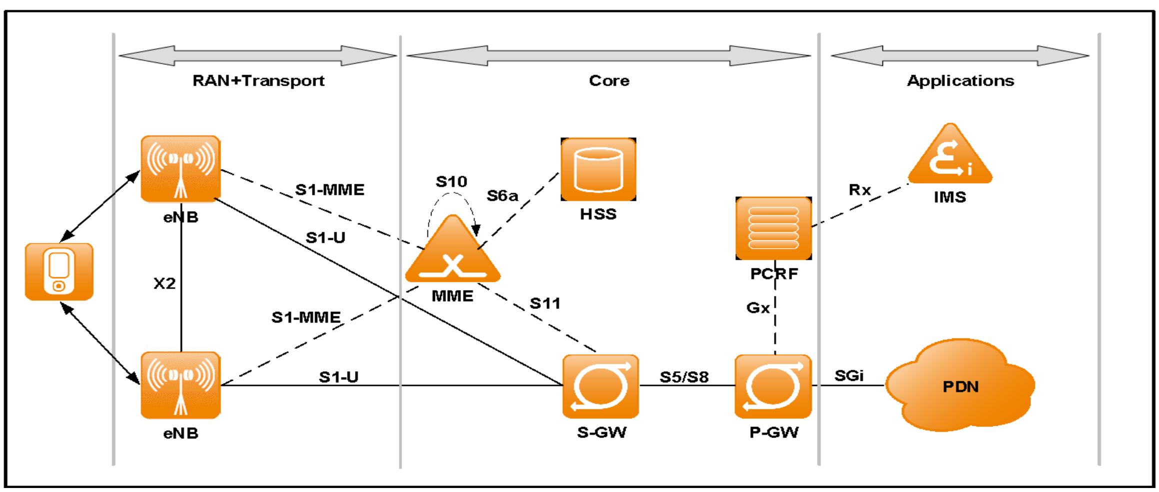

Figure 2.6. 4G architecture and IMS

In this architecture evolved NodeB (eNB) is replaced with RNC and Node B in 3G architecture. This replacement causes the connection to speed up and reduce the time required for handover.

The connection set-up time in real time data session like on-line gaming is important for end-user. Also, the handover time plays important role in quality of real-time services where end-users the end-to-end calls if the handover takes too long. The EPC is purely IP- based. Real-time and datacom services support the IP protocol.

The International Telecommunications Union-Radio Standardization Sector (ITU-R) targets peak data rates of about 100 Mb/s at speeds of up to 250 Km/H and Gb/s for low mobility access (pedestrian speed or fixed). The IEEE defines new framework to meet these requirements. In fact, integrating of IEEE 802.16 (WiMAX) with 100 Mb/s data rate at 250 km/h and IEEE 802.11 (Wi-Fi) with 1Gb/s at stationary or pedestrian is suitable solution to meet necessary requirements in 4G.

2.3 IMS and VANET integration review

In this section we are going to explain in details the integration available methods between IMS and VANETs.

As we mentioned above, it is desirable to provide road users with the Internet access in VANETs. In order to provide road user with the Internet services, each node in VANETs should communicate with RSU as stationary gateway [15].The communication range of stationary gateway cannot support vehicles with high speed because vehicles quickly move into and out of the communication range of the gateway. Thus, mobile gateways are taken into account in order to eliminate the limitation of stationary gateways [16].In this approach, the mobile gateway is embedded in the vehicle on the road which directly communicates to RSUs and other vehicles. Reference [17] presents the model for integrating VANETs and 3G technology. In this study, vehicles are clustered according to their velocity, their direction and inter-vehicle distances. In this scenario, vehicles are classified into Gateway Candidates (GWCs) and Ordinary Vehicles (OVs) based on using the Universal Terrestrial Radio Access Network (UTRAN) interface. Among the gateway candidates, a minimum number of Cluster Heads (CHs) are chosen as optimal gateway in each cluster. VANETs is linked to UMTS through these optimal gateways. In this scenario, we can see that, the gateway management is consisted of mobile gateway selection, gateway handover and gateway discovery/advertisement. In all the above cases mobility management is based on Mobile IP protocol, which is in network layer in OSI model. According to basic from [18] and [19], Mobile IP has some limitations including triangle routing , triangle registration, encapsulation overhead and need for home address. Although in IPv6 some problems are eliminated, we can see considerable delay in real-time multimedia services. Because of packets routing mechanism, triangular routing is formed among Home Agent, correspondent node and mobile node. In this process, updating the binding and tunnelling through Home Agent increase the hand-off delays[20]. Moreover, due to data encapsulation in Mobile IP and additional 16-byte address (the Home Address destination address) the payload should tend to decrease. Thus, significant low bit rate packet voice is causes by that. With advent of the IMS, the new doors open to VANETs world. The author in [21] justified the need of this integration. In fact, the real-time communication between vehicles, Session establishing with QoS, geographical position independency are the benefits of IMS and VANETs integration. m:Vía[22] designed an OBU in order to connect the vehicle to IMS through RSU. This on-board gateway has two main part including Application Unit (AU) and Back-end API for communication management. In [23] , a Back to Back User Agent (B2BUA) provides different SIP user agent in the vehicles. This unit is embedded in gateway. Also, in this article SIP protocol manages the mobility instead Mobile IP. According to characteristics of VANETs, each vehicle, which is equipped with OBU, moves between RSU with high speed. It causes frequently handover between RSUs. When the vehicle leaves the current RUS, the vehicle should cooperate with the current RSU and get the list of detected RSUs and the signal rate. Then, vehicle compares the strength of the signal and chooses the next possible one, depends on the direction and speed of the vehicle. All these scenarios result in considerable handover and it is possible that the user loses his/her connectivity with multimedia services.

2.3.1 Media Independent Handover (MIH)

Generally, this framework consists of three main elements including MIH function (MIHF), Service access point (SAPs) and MIH user. In the following Section, we introduce these elements and structure of them in MIH. Figure 2.7 illustrates the elements of MIH and the relation between them. Also, we can see the collaboration with them in order to improve handover functionality.

2.3.2 MIH elements

IEEE 802.21 defines specific services in order to facilitate the handover mechanism. In this part, we discuss responsibility and services of each element in MIH. Figure 2.7 illustrates the elements of MIH.

1.MIH function (MIHF):

The MIHF abstracts lower layer from upper layer. It obtains information from lower layer and transfer appropriate information, event or command to upper layer. It supports remote communication, which is occurred between to MIHF entities.

This element provides three different services in MIH. These Services play vital role in enabling handover. The first service, Media-Independent Event Service (MIES), reports link layer triggers. In fact, this service, according to signal strength (e.g. link-up or link- down) and any other changes in link layer properties, creates event (Link Event) and send it to MIHF. Also, it is possible that this service receives events From MIHF (MIHF Events).

The second one is Media-Independent Command Service (MICS). This service provides local and remote MIH users with set of commands. These commands are used to control and manage different link interface. The initiating of handover and querying of the target networks is preformed by this service. Remote commands are transferred with MIH protocol messages. Like events, commands can be exchanged between lower layer and MIHF and vise versa. The other service is the Media-Independent information service (MIIS). This service provides MIH framework with the information about heterogeneous neighboring networks, their topology, properties and their available services. This element prepares MIH to make decision for performing handover. The MIIS collects relevant information about networks in specific geographical area. This information is useful in order to make decision and execute effective handover.

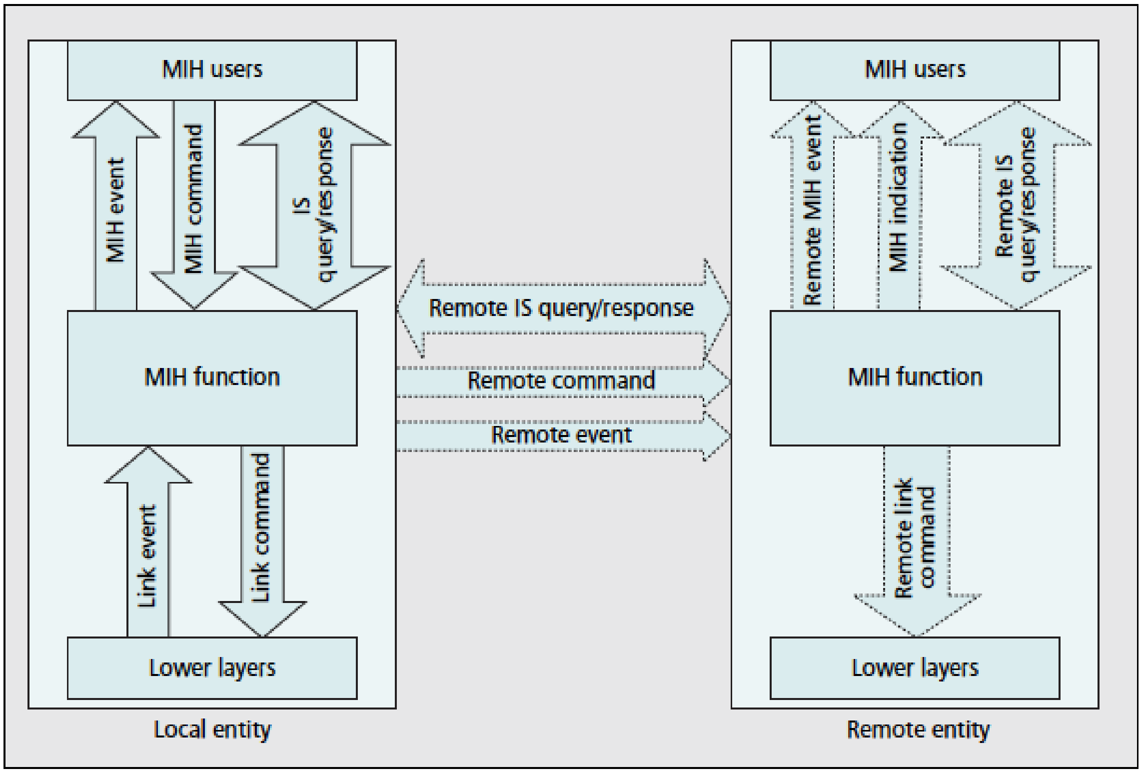

Figure 2.7. Communication between local and remote MIH entities[24]

2. Service Access points (SAPs):

This service provides MIHF with different access point in order to communicate with lower layer and upper layer. The former is named MIH_SAP provides a uniform interface for upper layers and monitor different links regardless of access technology. The later, which is named MIH_LINK_SAP, controls and monitors media link.

3. MIH user:

The MIH user can employ the all above entities.

2.4 Cloud Computing

As we observe in chapter one, Cloud Computing refers to application and services that run on distributed network while using virtualized resources and accessed by common Internet protocols. In fact, the use of the word ”Cloud” makes reference to two essential concepts: Abstraction and virtualization. In this section we learn more about Cloud computing.

2.4.1 Cloud Computing Models

Cloud Computing is separated into two distinct model including Service Model and Deployment Model [25]. Figure 2.8 shows the deployment model. The NIST defines Deployment Model As following:

- Public Cloud: The Public Cloud infrastructure is owned by an organization selling Cloud services to general public
- Private Cloud: The Private Cloud infrastructure is operated solely for one organization. A Private Clout is distinguished from traditional data center by technical improvements such as high availability and on-demand resources.
- Community Cloud: The Community Cloud infrastructure is deployed to serve services to several organizations.
- Hybrid Cloud: The Hybrid Cloud infrastructure combines two or more types of Cloud, such as private, public or community while each unit retains its identity in order to enable data and application portability.

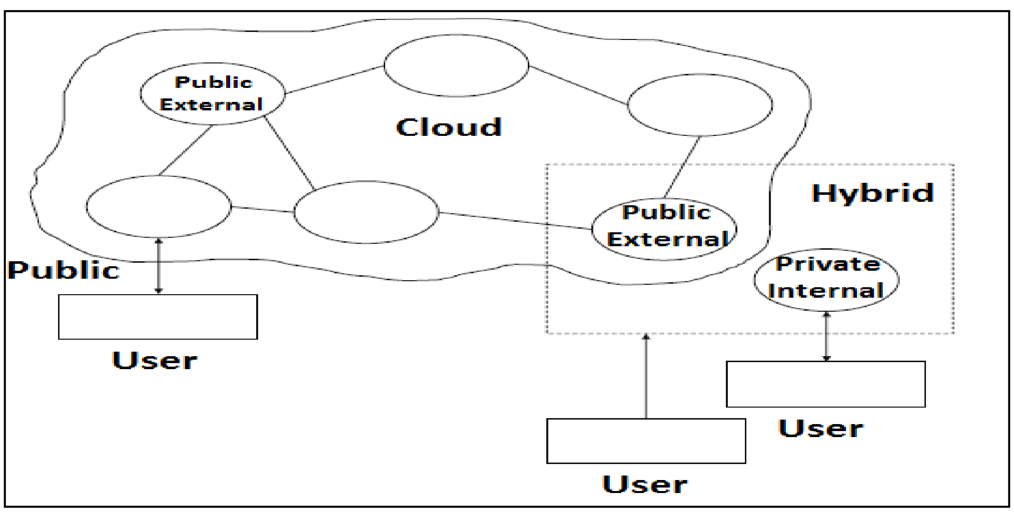

Figure 2.8.Deployment Model[26]

Also, we can consider the Service Model as following:

- Infrastructure as a Service: IaaS provides virtual machine, virtual storage and other resources.

- Platform as a Service: PaaS provides a model in order to abstract applications and services from implementation. A PaaS adds integration features, middleware and other services to the IaaS.
- Software as a Service: SaaS provides the access to software remotely as a web-based service.

Based on Figure 2.9 Called the Cloud Reference Model, we can observe that in the bottom of stack is hardware and resources. As you go up in the stack, it seams that each layer inherits the characteristics of underlying layer. In this model, the presence of middleware abstracts the structure of IaaS from SaaS.

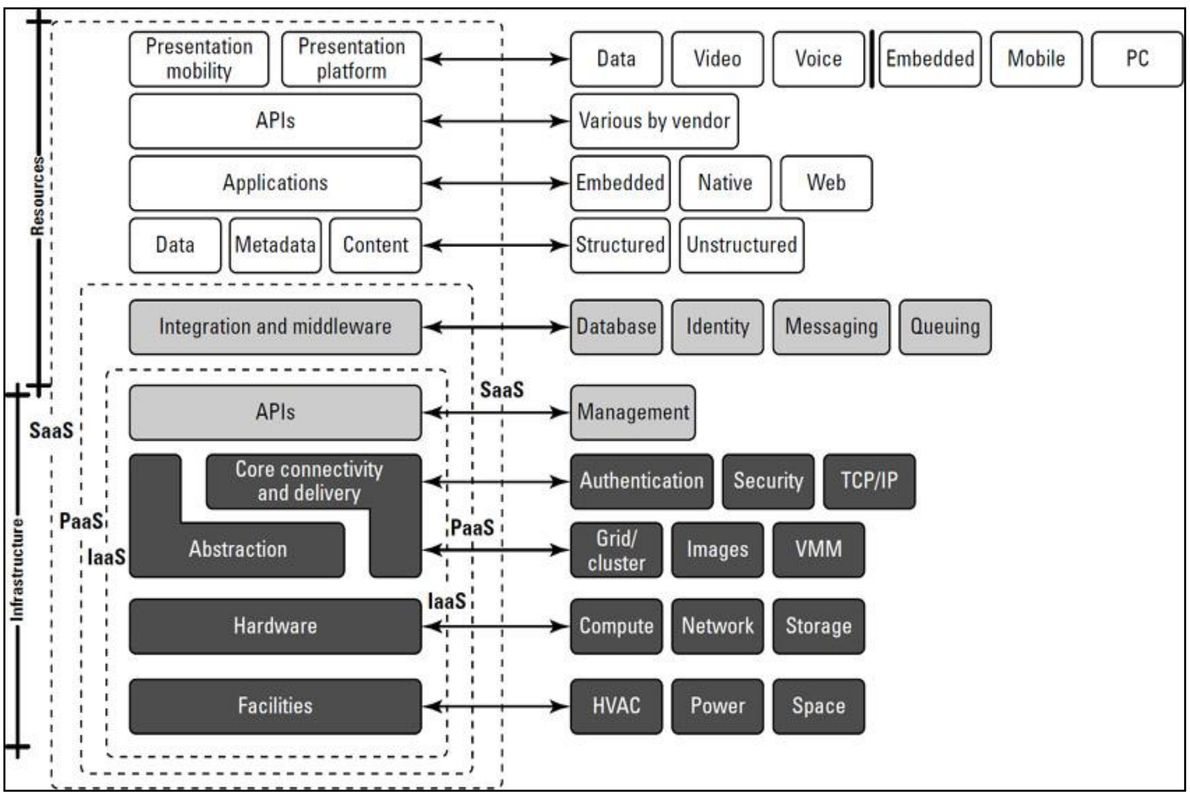

Figure 2.9.Cloud Computing Reference Model [3]

2.5 IMS and Cloud Computing

These days, IP Multimedia Subsystem provides many users with new services and applications. It causes the IMS to gain more and more interests from industry. By increase of IMS service demand, the traditional IMS infrastructure faces to set of problems. In traditional

IMS a set of SIP servers (e.g. CSCF entities) are dedicated to certain function. Moreover, the scalability of SIP is highly affected by the scalability of the front-end distributor, which relies on dedicated hardware and costs a lot[27]. Thus the performance of such system falls down, especially compared with the IT environment using Cloud Computing. The Cloud Computing offers high scalability and availability. So, the author in [28] has tendency to integrates Cloud Computing services into IMS network. The author presents IMS Cloud QoS system architecture, in which the lower layer (IaaS) is the development platform used for binding IMS with heterogeneous networks such as UMTS, WLAN and WiMax through IMS QoS policy. In this model, PaaS presents a platform for system administrator to develop Hadhoop technology needed for distributed file system and MapReduce technology. Finally, the SaaS provides the users with information and services via Cloud Computing system.

This proposal could be adapted to our case where the road user access IMS services through Cloud Computing.

Now that we have described methods to integrate VANETS, IMS and Cloud computing, we could say that the appropriate middleware design in Cloud Computing architecture is acceptable solution to support road users in VANETs with high Quality of Service.

CHAPTER 3 PROPOSED ARCHITECTURE

As many users spend long times in their vehicles, it will be interesting to provide them with IMS services in their cars. Giving access to the IMS through VANET connectivity will be an evolution of VANET. This chapter proposes a new architecture to integrate VANET and Cloud based IMS. Firstly, the design and basis of the proposal are explained. This part includes assumptions, principles, elements and topology of the architecture. Later on, the rules, which govern the architecture, are described. The information model, the protocol and the procedures are also presented. Finally, the scenario using the proposed architecture is explored.

3.1 Proposed Architecture

VANET is highly dynamic ad hoc network with restricted access to the network infrastructure. Therefore, it is hard to maintain ubiquitous connectivity and guarantee acceptable QoS in terms of data loss, jitter and latency during the handover of vehicles from one network to another one. On the other hand, ubiquitous connectivity should be provided in secure situation with acceptable QoS. It is necessary to support vehicle with authentication, confidentiality and integrity during data transferring with the other vehicles and network infrastructure. In this proposed architecture, to provide vehicles with multimedia services, we choose IMS infrastructure. The reasons of this choice are as follows:

1. VANET can benefit from different technologies to access to a network infrastructure such as Wi-Fi, 3G and LTE. IMS can support network heterogeneity.
2. IMS enables communication between vehicles in real-time with QoS parameters, as well as provides vehicles with new integrated QoS-gauranteed multimedia services. This happens, independently from geographical location of vehicles. For instance, SIP could be used as mobility management protocol and QoS infrastructure of IMS.
3. It is well-known that authentication and authorization are very critical and mandatory in VANET. IMS provides maximum security through reliable authentication and authorization of users. It can be based on widely used protocols such as SIP, SDP, RTP and Diameter. The identities are managed through Universal Resource Identifier (URI). All of these are supported in IMS infrastructure.

As it is mentioned before, all the above functions have been done by RSUs without IMS infrastructure. Thus, the QoS is lower due to exceeded handover among RSUs in different networks and low throughput.

Cloud Computing service provider can support their customers with more reliable and available services such as multimedia services. Service providers are able to use resource pooling to enhance their services. The advantage is to offer cheaper services with more quality and performance. «Cloudifying» the network elements of the IMS framework in order to take advantage of key benefits of the cloud like elasticity and the utility style pricing, is the other goal of this proposed architecture. We can follow the benefits of cloud deployment for the IMS:

1. Enable the users of IMS to benefit of high speed and imaginative new service that combine voice, data, video and mobility.
2. Enable the service provider to be away with Capital Expenditure involved in buying the software and hardware for CSCF.
3. Enable the service provider to start with small deployment and grow based on number of subscribers and network traffic.

In this chapter, we propose the mobile gateway as a simple and straightforward solution to provide VANET with multimedia services in Cloud Computing through the IMS. This gateway should be able to communicate with service provider in Cloud and VANET directly. This can be executed by the middleware and processing entities found within the architecture of the gateway. Therefore, the gateway should be able to publish VANET information to service provider who supports the road users of VANETs with IMS services in Cloud Computing. Moreover, we will present a new architecture for Cloud provider. In this architecture, Cloud provider deploys the IMS core network and special application servers to provide the road users in VANET with multimedia services. The Cloud provider deploys IMS infrastructure as a new service to support the end user with higher QoS.

We propose a gateway architecture and Cloud based IMS architecture to fulfill the defined needs and we design the solution from this decision. Following the detailed presentation of the architecture, an analysis on how the requirements are met by the proposal will be done in chapter IV.

3.2 Assumption

Our idea is to provide a gateway to interconnect Cloud based IMS and VANET. We assume that all entities of the system (i.e. VANET, gateway and IMS) are configured to know each other. Additionally, we assume that all mobile nodes (i.e. Vehicles) in are equipped with mobile gateways. The mobile gateway is capable to communicate to 4G-backhaul networks via appropriate network interface. Vehicles can also move in different directions with different speeds.

However, the design of the architecture ensures that minimal changes and adjustments could be made such as the format changes.

3.3 Architecture Principles

The principles of our architecture are based on three layers including device layer, transport layer and service layer. The figure 3.1 illustrates the general architecture.

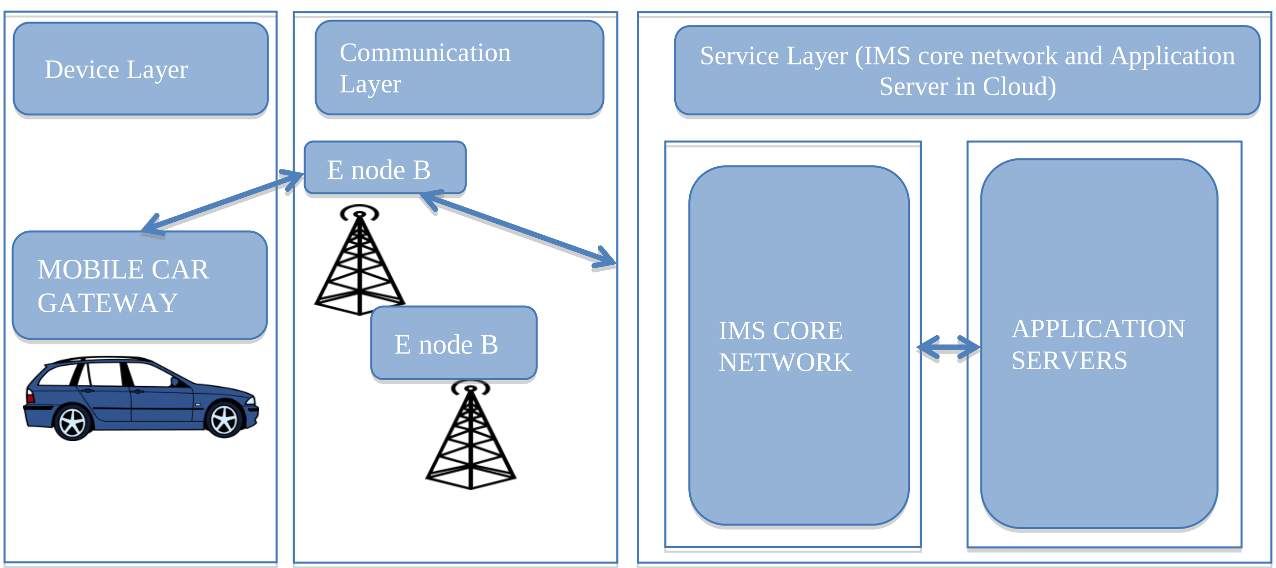

Figure 3.1. Three-layer IMS based Cloud Services general architecture

The general architecture (Figure 3.1) indicates a novel three-tier Cloud Based IMS architecture for VANET from functioning point of view. By integrating VANET, IMS and Cloud Computing techniques, we aim to provide the users with: (i) real-time services with high QoS, (ii) sharing and cheap services. The vehicles, which are equipped with mobile gateway, belong to the first layer. We assume that the mobile gateway is capable to communicate to 4G-backhaul networks via appropriate network interface.

The mobile gateway of vehicle can connect to the IP network in the transport layer via a variety of transmission media, including Wi-Fi (a wireless local area networks technology), 3G and 4G. In this architecture, we choose enode B as base station to connect vehicles to 4G networks.

All the vehicles classified in first layer can communicate via second layer with cloud based IMS core network in third layer. All the Cloud services which road users are subscribed to are available through the IMS core network. In fact, this core network controls and manages all the data transaction between application servers in cloud and road users in VANET.

To meet above requirements in our architecture, we focus on device and service layers of our architecture. The existence of mobile gateway in device layer is very important because via this gateway the users can communicate to service layer to benefit from multimedia services. On the other hand, to improve the quality of multimedia services, we need novel architecture based on Cloud Computing and IMS that is proposed in service layer of our architecture. Firstly, we explain the topology of our mobile gateway in first layer. After that, we present appropriate architecture for cloud provider providing multimedia services to road users in VANET while using IMS core network.

3.4 Architecture topology and interactions

As depicted in figure 3.2, first, the service provider of IMS services in Cloud has to authorize the end user to use the services. This typically requires a subscription or contract between the service provider and end user in VANET. Then, in second step, the vehicle equipped with mobile gateway requires registering with service provider to authentication, authorization and accounting. In fact, service provider has to know which services and level of QoS the end user subscribes to. In this case, service provider deploys the IMS core infrastructure as a service to manage and control the session as well as user authorization and authentication. Afterwards, in third and forth step, the vehicle sends request and receives the service from service provider in cloud, respectively.

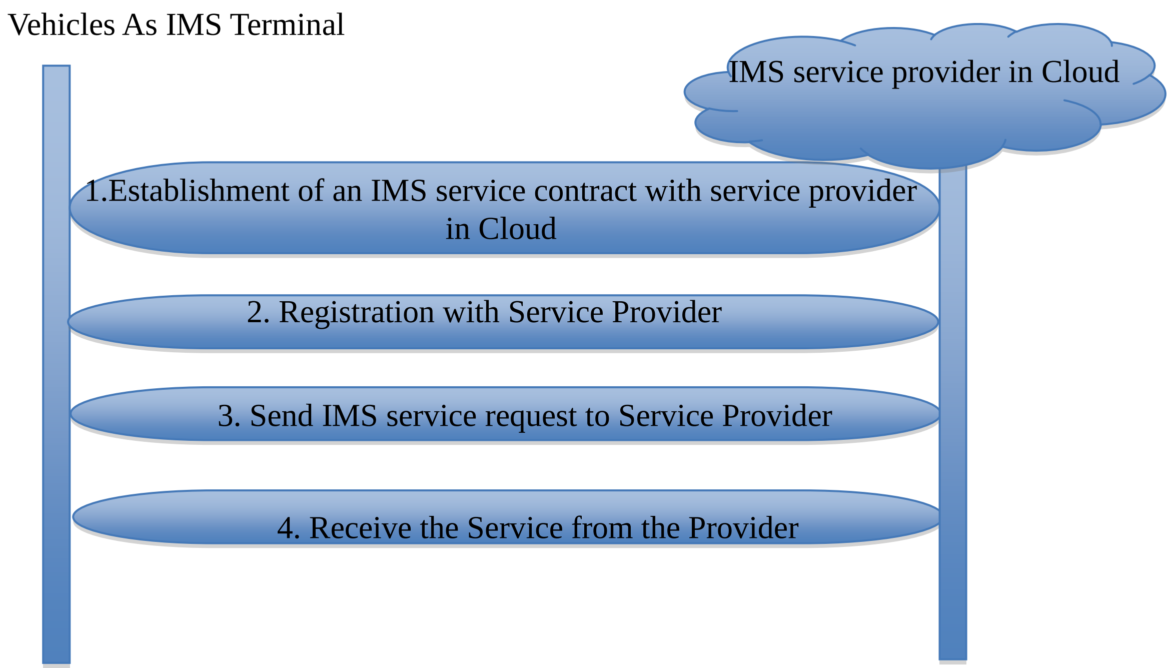

Figure 3.2. Prerequisites to get IMS services in Cloud

Figure 3.3 presents the topology of three-layer architecture components. Vehicle is equipped with a gateway. The Cloud provider enables IMS services to Vehicles.

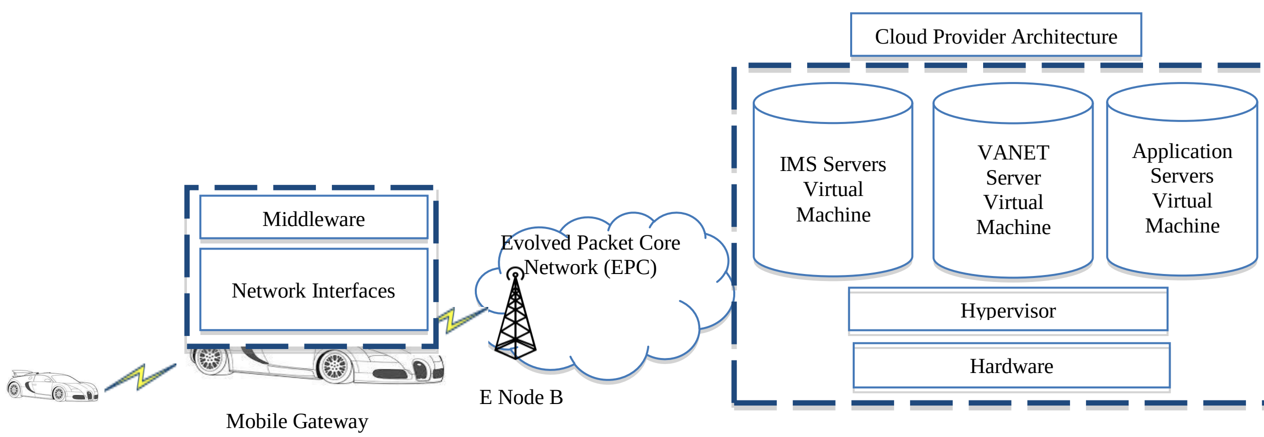

Figure 3.3. Architecture topology

In the first layer of proposed three-layer architecture, there are some nodes of VANET, which are equipped with On-Board Unit (OBU). The OBU interacts with the mobile gateway. It is assumed that OBU is equipped with Application Unit (AU), dual interfaces of IEEE 802.11p and the 4G networks, GPS devices, and also experiencing different 4G-signal strength intensities at different regions. The AU of the OBU can determine a set of communication parameters (i.e.

QoS, delay-time, packet loss tolerance, jitter...). The AU can also provide application interface to communicate with the service provider in order to select the desired service in cloud. When the communication channel is created, the driver and passengers can get relevant services. The OBU is capable to report to the Mobile Gateway, the situation of the vehicle such as the available bandwidth. A mobile gateway refers to the dual-interfaced vehicle that relays data from VANET to the Cloud Based IMS architecture. It is equipped with dual interfaces of IEEE 802.11p and the 4G networks. Therefore, the gateway can report information to the service provider in Cloud. Both the mobile gateway and OBU can communicate with Evolved Node Bs (eNodeBs). These base stations through Evolved Packet Core Network (EPC) connect to the cloud. To meet the requirements of our architecture, this proposed mobile gateway has two main tiers. (These tiers will be discussed in 3.4.1 section in details). Bellow, we can follow these tiers of the gateway briefly:

1. Middleware Tier: this unit processes the received information and depends on them. It stores, compares and distributes information among another units.
2. Network access: There are two network access interfaces in this tier to communicate with VANET and 4G.

The second layer of the proposed three-layer architecture is the communication layer. The main element in this layer is 4G networks. The main motivation in IMT-Advanced (4G) networks is higher data rate to deliver wireless services competitive with broadband wire line. To achieve this goal, two radio accesses technologies IEEE 802.11 (1 Gb/s, low velocity) and IEEE 802.16 (100 Mb/s, 250 Km/h) are combined to introduce emerging IEEE standard for media independent handover services named IEEE 802.21. This new standard supports seamless mobility between two radio access technologies. The 4G networks can coordinate with nodes in VANET to deliver higher data rates wireless services.

The third layer of the proposed three-layer architecture is the service layer. In this layer, the IMS core network is deployed as new services in order to provide VANET with multimedia services. As shown in figure 3.4, IMS core network infrastructure, VAVET Server and Application Server are considered as services, which are provided by cloud provider. They are executed on virtual machines in Cloud Computing. These servers handle all the information received from vehicle, manage the mobility in application layer when session is established to provide the multimedia services.

A Proxy Call Server Control Function (P-CSCF), Interrogating Call Server Control Function (I-CSCF), Serving Call Server Control Function (S-CSCF) and Home Subscriber Service (HSS) constitute the IMS core network. All the SIP messages from the road users (such as INVITE, REGISTER, SUBSCRIBE) should pass via the P-CSCF to reach the IMS core as new service in Cloud Computing.

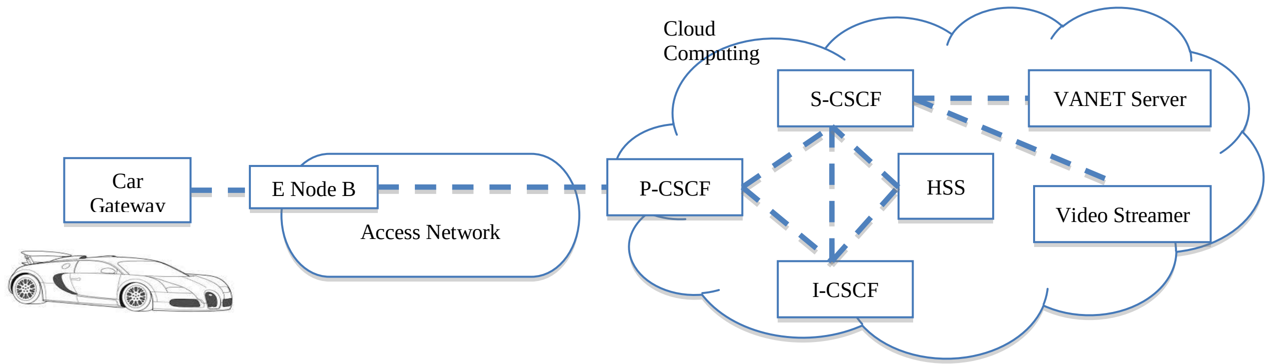

Figure 3.4. The Cloud Services

The P-CSCF forwards the road user SIP request to the appropriate I/S-CSCF depending on certain information obtained from HSS. After successful authentication and authorization, the road users receive the requested services from IMS core network.

Besides the IMS core network, there are two main servers in this layer. The VANET server, which acts as the presence server, keeps the presence information of the vehicles. This server has an interface with S-CSCF. The S-CSCF forwards the related messages from road user to this server. It also passes messages from VANET server to road users. The Video Streamer Server has an interface with S-CSCF in order to get status information of the vehicles subscribed from VANET Server to them. When the VANET Server receives new published message from the vehicle, it notifies the application servers subscribing to that vehicle through S-CSCF.

To provide the communication among road user, VANET Server and AS, we utilize Session Initiation Protocol (SIP), SUBSCRIBE, NOTIFY and PUBLISH messages defining by Internet Engineering Task Force (IETF) SIP for Instant Messaging and Presence Leveraging extension (SIMPLE) working group.

3.4.1 Roles of defined Units in Gateway Architecture

The proposed gateway has two main tiers. Each tier consists of components and has specific roles. In following, we consider the roles of each tier.

As shown in figure 3.5, the first tier is the middleware. It consists of processors, storage and translator. This tier is in charge of accepting, storing and distributing presence information based on SIP messages. The Presence Manage Unit (PMU) is an entity that accepts, stores and publishes presence information of the vehicles based on SIP protocols. This unit manages presence state (and location) publication from vehicles. It can refresh and replace existing presence information with newly published information. The PMU publishes messages when the situation of the vehicle is changed. The middleware gets information such as available bandwidth, position and signal strength from the third tier. The achieved information is processed and translated to SIP Publish request by the processor and the translator of this tier.

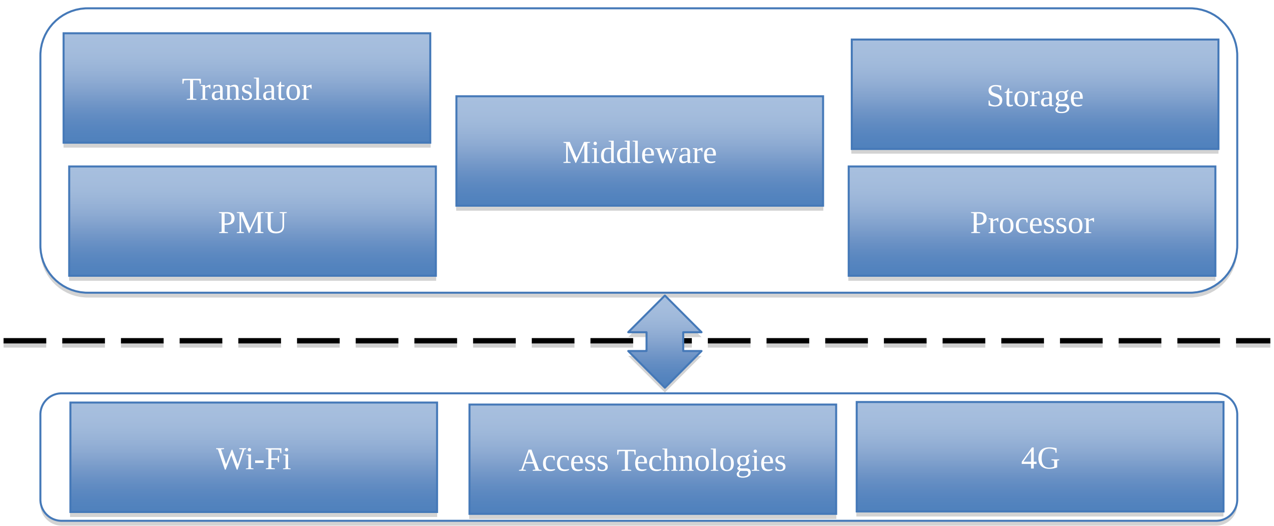

Figure 3.5. The gateway architecture

The third tier is in charge of controlling the access technology. There are two main network interfaces in this tier: Wi-Fi access network interface and 4G back-haul access network interface. The Wi-Fi access network interface is used for communicating with the other vehicles. This tier receives the requests of the other vehicles. Then, the request will be forwarded to middleware for processing and translating. After processing and translating, the middleware prepares the request to send toward Cloud Based IMS. Therefore, middleware retransmits the request to the third tier which is sent to the Cloud Based IMS via 4G interfaces. Also, this tier can provide the middleware with useful information. The middleware uses the information to notify the Servers in Cloud to manage the application bandwidth.

3.4.2 Roles of defined servers in Cloud

In this part, we explain the roles of the servers located in Cloud. As shown in figure 3, IMS Servers (including P-CSCF, I-CSCF and S-CSCF, HSS and SLF databases), VANET Server and Video servers are the main Cloud servers providing services. All these servers are running over the virtual networks in cloud. They are in charge of managing and controlling the SIP session.

All the SIP messages among vehicles and Servers in Cloud Computing Architecture are routed through the IMS servers in Cloud Computing Architecture. In fact, The IMS core network is laid between access network (4G back-haul network) and application servers in Cloud Computing. In this architecture, we can use the features of IMS core network to control security and QoS of established SIP session.

In this architecture, VANET Server acts as Presence Server in IMS. However, this server has just handled the SIP messages between vehicles and application server in Cloud. VANET Server provides application servers with presentity's information of vehicles. To provide the presentity information of vehicle to VANET server, we utilize the SIP Subscribe, Notify, and Publish messages defined by Internet Engineering Task Force (IETF) SIP for Instant Message and Presence Leveraging Extension (SIMPLE) working group.

3.4.3 Interactions

In this part, we explain how message exchange and communication will be occurred among between VANETs and cloud provider.

The Scenario

In this scenario, the vehicle equipped with mobile gateways wants to establish the session with Application Server in Cloud based IMS. It is obvious that the road users have contract with service provider to utilize IMS services through Cloud Computing. The vehicles use SIP request to establish SIP session with Application Server in cloud based IMS. All the requests are passed through CSCFs servers to establish, manage and terminate the session. Furthermore, because of high mobility of vehicles in VANET, the vehicle should send periodically their position and available bandwidth with SIP method to VANET Servers. Then, the VANET Server communicates with associated application server to notify the application server about the presentity's information of the vehicles. VANET server and application servers communicate with each other with SIP protocol via CSCFs servers described in following sessions.

After vehicles gains IP address through DHCP servers and also discovers the IP address of its P-CSCF, it can begin registration with IMS core network. This IMS-Level registration can authenticate and authorize the road user to access the IMS services. Then, it can establish the session with Cloud Based IMS Servers to use multimedia services. Via the application interface, which is embedded on OBU, the road user can choose which service, he or she wants to use. For instance, we can imagine that a passenger in the vehicle want to watch a video. In this scenario the mobile gateway is able to get state information of the vehicle. The state information of each node in VANET includes current location, speed, direction and QoS level such as available resource and bandwidth. The OBU transmits this information periodically with beacon messages. In figure 3.6, the details about how the proposed mobile gateway and cloud based IMS interact with each other is presented.

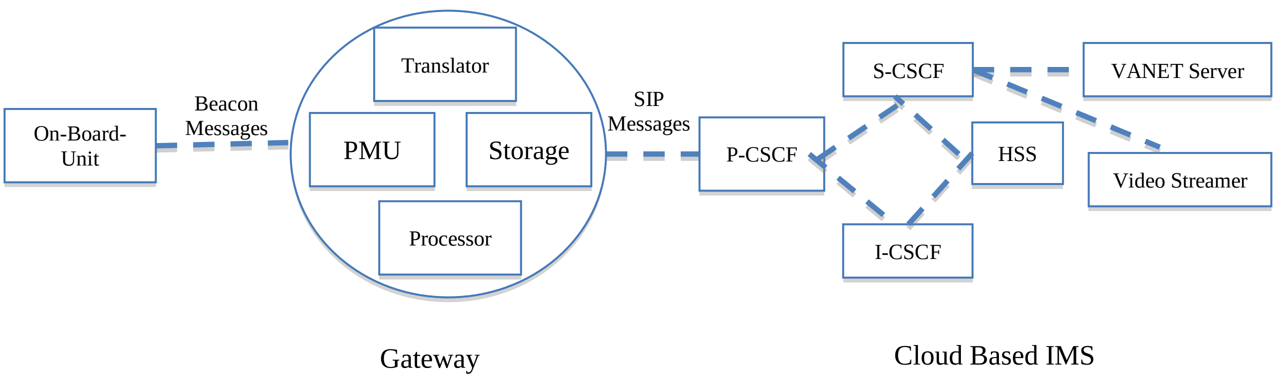

Figure 3.6. Interaction between Gateway and Cloud Base IMS

The mobile gateway receives these beacon messages and compares them with the last one received previously. If the content of Beacon messages changed (e.g. bandwidth), the gateway processes them to compose SIP PUBLISH messages. In this process the translator, PMU, processor and storage units are involved to create SIP PUBLISH request. According to the appropriate field in message body of the SIP PUBLISH request, it is routed through access network to P-CSCF server. All the SIP requests in IMS core network are passed through P-CSCF. The P-CSCF receives these SIP PUBLISH messages and forwards to S-CSCF. The S-CSCF evaluates the initial filter criteria. In this architecture, one of the initial filter criteria indicates that the PUBLISH messages should be forwarded to VANET Server where the presentity's information of the vehicles are stored. So, S-CSCF forwards Publish Request to

VANET server. After receiving the PUBLISH Request, the VANET server sends response. By receiving new state information of road user, the VANET server checks the subscription and finds the application server subscribing to presentity's information of that vehicle. The VANET Server uses the SIP SUSCRIBE message to inform the application server. In this case, when the road user chooses the service and attempts to establish the connection to the Cloud provider to watch a real-time video, the available bandwidth and the other state information of the vehicle are available. The gateway can notify the application servers about any bandwidth changes occurred due to high mobility. Therefore, the video server in Cloud Based IMS can stream the video depend on the available bandwidth of the vehicle. This approach avoids exceeded packet lost, jitter and delay. In fact, in this scenario the application server is able to respond to radio link changes during the session. Therefore, real-time or streaming application continuity and QoS are preserved during handover.

3.5 Global Architecture

The architecture, its components' roles and its topology have been explained in a detailed way. Afterward, we show how vehicles are connected and integrated to Cloud Based IMS. At this point, the topology and the basic of the integration will be described, the process on how they are connected to each other is explained below in the next subsection. The following figure 3.7 shows the proposed architecture.

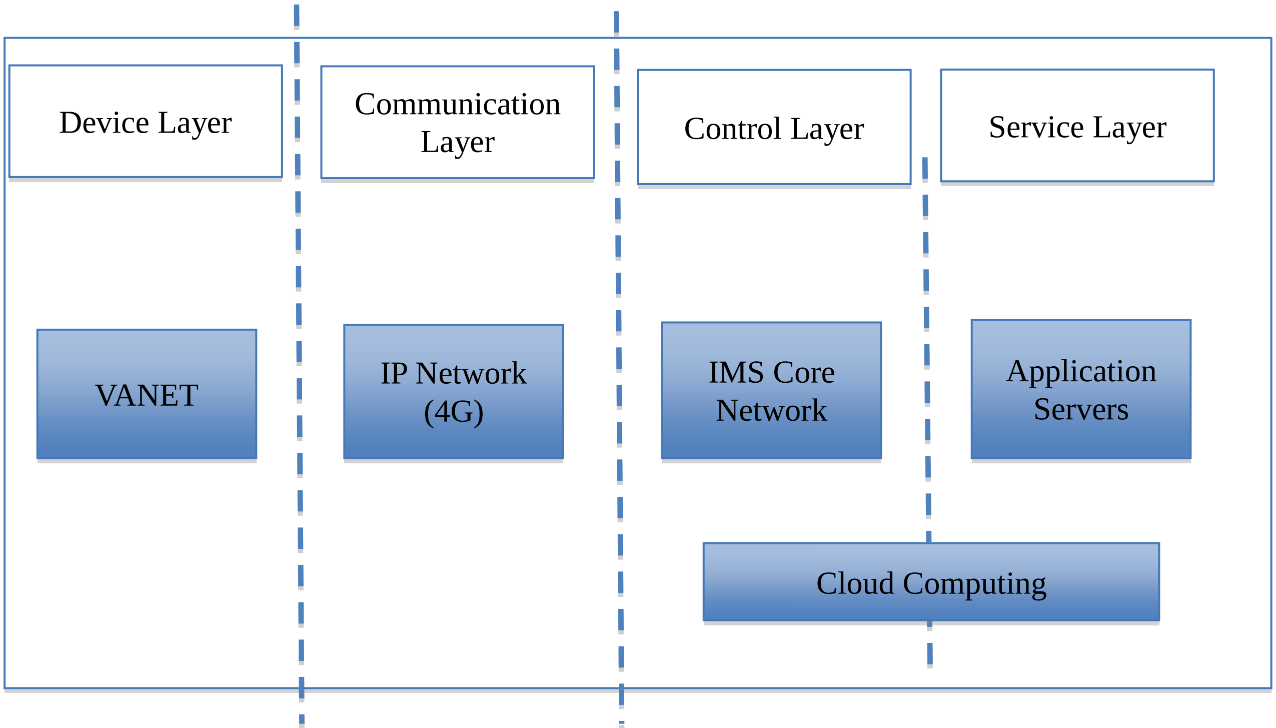

Figure 3.7. Global topology of the proposed architecture

3.6 Protocols

The main protocol of the IMS is SIP that is originally developed within the SIP working group in the IETF. SIP is a standard protocol, widely deployed and easily extensible.

SIP methods

Presence is a service that allows a user to be informed about the reachability, availability, and willingness of communication of another user. IMS already has presence service well supported in its architecture in Service layer.In fact, the IMS terminal uses the SIP Publish method to publish the current presentity's presence information. The IMS terminal sends a PUBLISH request that contains an Event Header set to presence and includes a Presence Information Data Format (PIDF) document that describes the presence information. In the next step, the S-CSCF receives and evaluates the request. The S-CSCF evaluates the initial filter criteria and forwards the Publish request to Presence Server (PS), where the presentity's information is stored. Afterwards, the PS authorizes the publication and sends 200 (OK) response. Apart from the IMS terminal, the other network entity such as gateway, proxy servers can act as the source of presence information and publish the user's presence information.

The SUBSCRIBE / NOTIFY methods included within the RFC3265 (Session Initiation Protocol – Specific Event Notification) [28] provides an option for asynchronous notification of events. The event-notification framework is proposed to enable entities in the network to subscribe to receive the current state or updates from a remote node. If the state changes in the remote node, NOTIFY messages are used to inform subscribers. The Presence Framework, for instance, uses this extension to control the vehicles registered to each “presentity”. This event-notification framework enables the creation of groups inside the gateway when the information needs to be disseminated from the super node “leader” to one or several participants in an asynchronous way.

3.7 Message follow

In this section, we consider the interaction among road user of VANET, Cloud provider; IMS core network. All the messages routed must be followed among them.

The publish unit of middleware in gateway is in charge of publishing the presentity’s information of vehicles. This publish unit sends SIP PUBLISH message to the VANET server. As we mentioned before, presentity’s information of vehicle is sent in the body messages.It is a XML document called PIDF. IMS CSCFs forward the request to VANET Server which act as Presence Server. Note that the publish unit sends this message to the VANET server in the initial stage or when the statues of the vehicle is changed. The vehicle sends bandwidth and location to VANET Server with PUBLISH request to VANET server. In PIDF document, we can add new topple for bandwidth information. When VANET Server receives the PUBLISH request, it replies with 200 OK answer.

Moreover, the application servers belongs to cloud provider are subscribed to VANET server. The application server, for example video streamer, sends SUBSCRIBE message to VANET server. By sending SUBSCRIBE messages, the application servers obtain the status of the vehicle. Therefore, the application servers transmit suitable flow of data to road user. In this case, VANET server also acts as a Presence Server to accept SIP request and then replies with 200 OK to the application servers.

The VANET server checks the subscription list and finds that the Application Server has subscribed the status of Vehicle. Then, the VANET server sends SIP NOTIFY message to inform the application server about any changes in vehicle's status. Upon receipt of the NOTIFY message, the Application Server replies 200 OK message.

When the user attempts to watch real-time video, the vehicle sends SIP INVITE message to application Server. This SIP INVITE message contains the Universal Resource Identifier (URI) of the application Server and carries the play command. This message is routed through IMS CSCFs to application server. When Application Server receives INVITE message, it starts to prepare the request video and replies with 200 OK to the vehicle. Afterwards, upon vehicle receives the 200 Ok message, it sends an ACK message. The session for real time multimedia is then established. In this time, the application server can control the flow of data because it can obtain the status of the vehicle from VANET server with SIP requests.

Sequence diagram

In this section, we consider the message flow in details with sequence diagram. Sequence diagram presents a dynamic view of the system. It is possible to track the messages, their status and to have knowledge at any moment about the messages status. Figure 3.8, presents a message follow.

Step 1-Registration

If the road user wants to benefit from Cloud Based IMS, the first step is IMS-level registration. Based on figure 3.8, the vehicle as IMS client sends the SIP REGISTER request (1) to P-CSCF. Then, the P-CSCF finds the address of I-CSCF from the Domain Name System (DNS) server and forwards the SIP REGISTER (2) request to I-CSCF. The I-CSCF fetches the user location information from HSS based on Diameter protocol (RFC 3588)(3). It sends User Authentication Request (UAR) to HSS for user authorization and S-CSCF allocation. According to User authentication Answer (UAA) (4) that is returned by the HSS, the SIP REGISTER request (5) is sent to S-CSCF. If authentication is successful, the S-CSCF sends the Diameter Server Assignment Request (SAR) (6) message to HSS to notify that the user is now registered. The HSS sends Server Assignment Answer (SAA) (7) with user profile. The user profile consists of all information about Public User Identities and Private User Identity to authenticate the road users. Finally, the S-CSCF sends 200 (ok) response to SIP REGISTER request to indicate the successful IMS-level registration.

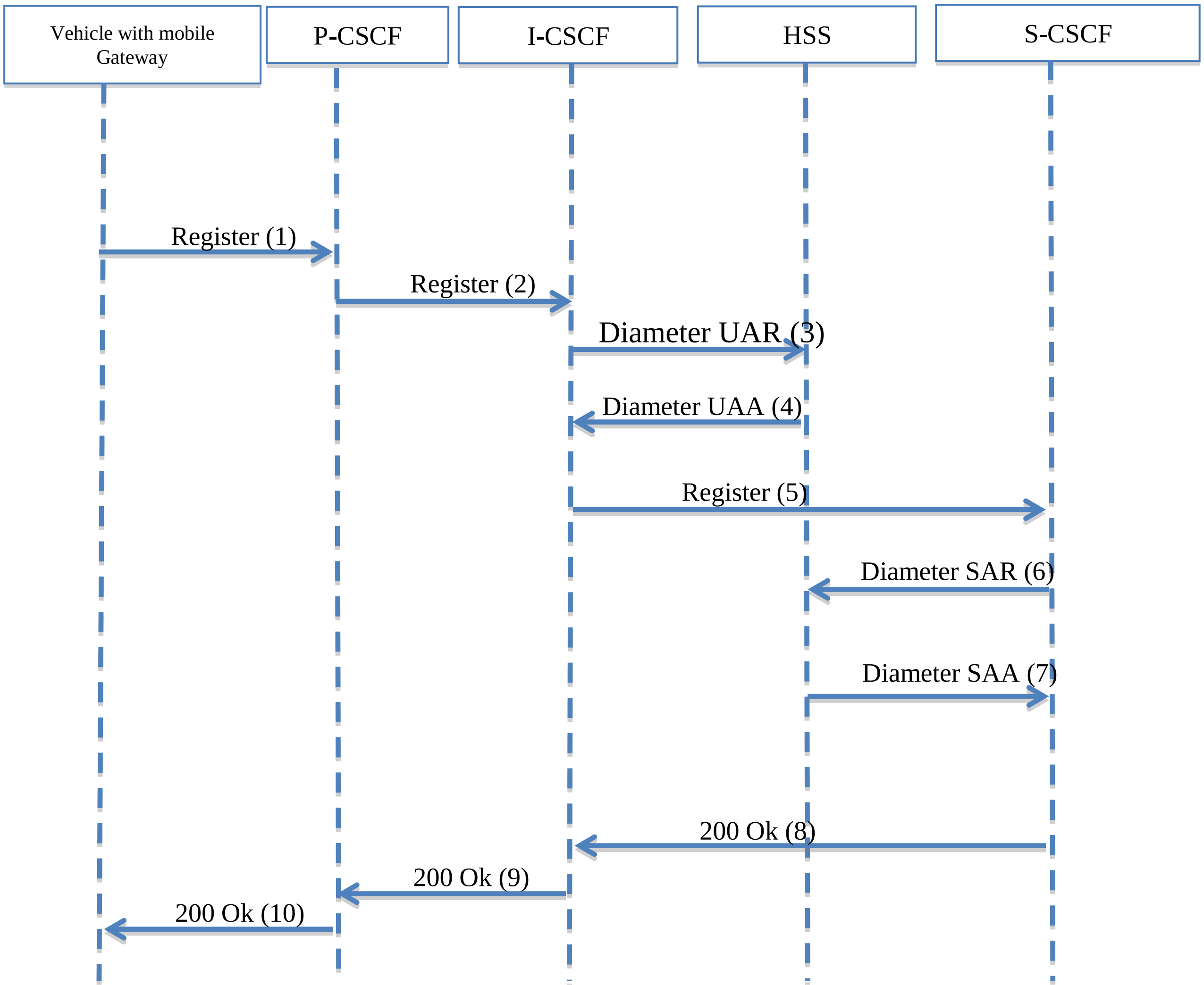

Figure 3.8. SIP REGISTRAION Signalling

Step 2- Publish State Information

In the initial stage, the application server utilizes a SIP SUBSCRIBE message to obtain the status of the vehicle equipped with mobile gateway. The application server sends SIP SUBSCRIBE message to VANET server. As we can see in figure 3.9, S-CSCF is in charge of routing SIP SUBSCRIBE (1) message from application server to VANET Server.

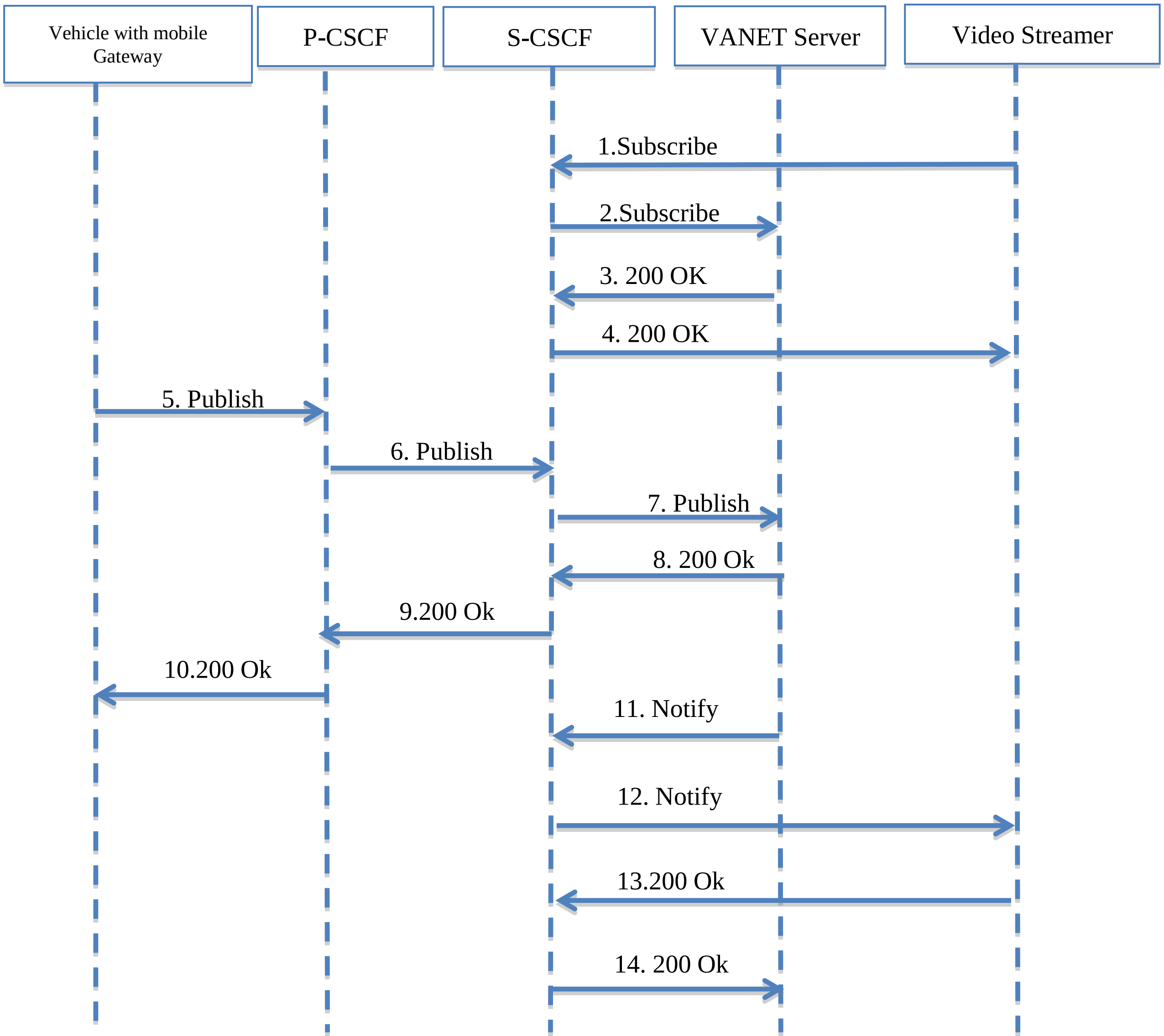

Figure 3.9. SIP Signalling

The SIP SUBSCRIBE is received at the S-CSCF which evaluates the initial filter criteria. The evaluation indicates that SIP SUBSCRIBE message ought to be forwarded to VANET Server. The VANET Server receives SIP SUBSCRIBE message (2). After verifying the identity of the subscriber and authorizing the subscription, the VANET Server sends a 200 (OK) response (3). The S-CSCF receives 200 (ok) and passes 200 (ok) message to Application Server (4). Thus, the Application Server subscribes to the state information of the vehicles.

The VANET Server has the interface to related data centers in cloud that stores the lists of Present document of the registered vehicles. The VANET server fetches required information from these documents to presence to the subscribe watchers or to modify them with new information when it receives SIP PUBLISH request.

The vehicle equipped with mobile gateway announces its status (i.e., available bandwidth) to VANET Server. It sends SIP PUBLISH request (5). The request contains an event header set to presence and includes a PIDF document. The document describes the presence information to P-CSCF. The P-CSCF receives the SIP PUBLISH request and forwards SIP PUBLISH request (6) to S-CSCF. The S-CSCF receives the request and evaluates the initial filter criteria. The initial filter criteria indicates that the SIP PUBLISH request with event header presence should be sent to VANET server. Therefore, the S-CSCF forwards the PUBLISH request (7) to the VANET Server. The VANET server authorizes the publication and sends 200 (OK) response (8) to S-CSCF. Then, the S-CSCF transmits 200 (ok) (9) to P-CSCF. Finally, 200 (ok) message is sent to IMS Client (Vehicle) (10).

When VANET server receives new SIP PUBLISH request, the VANET server checks the subscription list and finds the application server subscribed to the status of the identified vehicle. The VANET server uses SIP NOTIFY message to inform the application server. Therefore, the VANET Server send SIP NOTIFY message to S-CSCF (11). The SIP NOTIFY message contains new presentity's presence information. The S-CSCF sends the SIP NOTIFY message to Application Server (Video Streamer) (12).

Step 3- Establish SIP session with Application Server to watch the video

In this step, the vehicle with mobile gateway publishes the new state information. The application server is notified about new state information of the vehicle. So, when the user wants to establish the connection, the application server knows the QoS available and parameters.

As shown in figure 3.10, the Application unit of mobile gateway sends a SIP INVITE (1) message to establish the connection. The P-CSCF as the entry node of IMS core network receives the invite message and sends the SIP INVITE message to S-CSCF (2). The S-CSCF checks the filter criteria and forwards the request to Video Streamer.

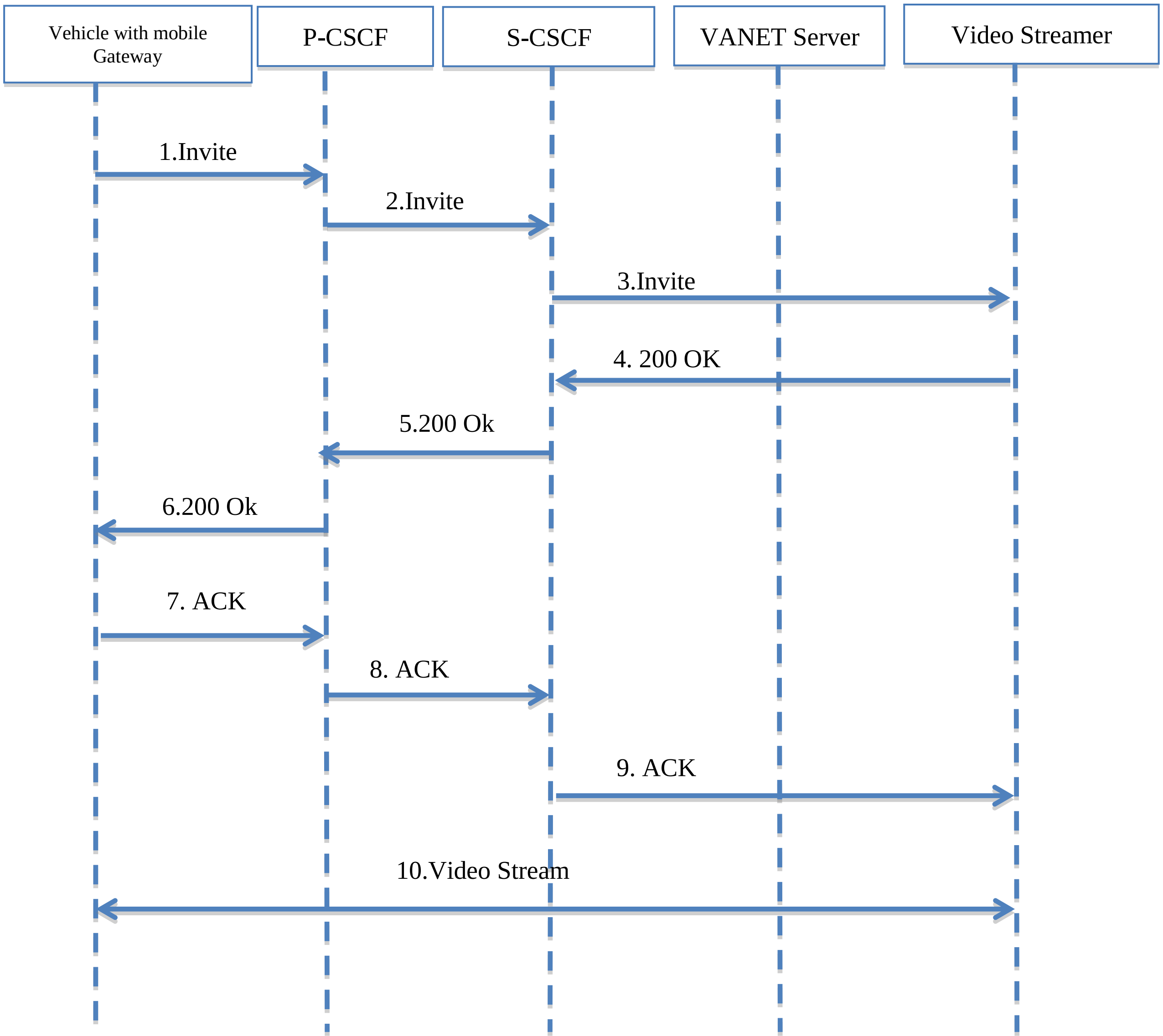

Figure 3.10. SIP INVITE Signalling

The video streamer receives the SIP INVITE message and replies 200 (ok) message (4). This message is routed to the user via S-CSCF (5) and P-CSCF (6). When the user receives 200 (ok) messages it sends ACK messages (7). Thus, the session is established and the road user can watch real-time video.

Chapter 4 Implementation and validation

In this previous chapter, we explain our proposed architecture in detail. Now, we want to validate our work to guarantee that it certainly improves the function of Multimedia services in VANET.

This chapter shows the process of the implementation and validation of the proposed architecture in the previous chapter. First of all, as implementation, we analyze the performance of our new architecture as compared to the other architectures that are based on traditional IMS architecture without 4G technologies. Early in the first section we define mathematical models for validating our work. Then we present the numerical results and the last section will be dedicated to analyzing the results.

4.1 Mathematical Model

In this section, we defined mathematical models to evaluate our proposed architecture. First of all, we analyze the system latency of our architecture as compared to another architecture in the literature. In fact, latency is one of important quantitative metrics that is used to evaluate the performance of the system or the architecture.

Latency is the amount of time it takes a packet to travel from source to destination. According to our architecture, latency is the amount of time that message of the vehicle reaches the mobile gateway and then, appropriated SIP Publish request from mobile gateway places on IMS application server in Cloud through LTE access network and EPC.

In order to form mathematical model to evaluate the proposed architecture, we consider some parameters. These parameters are driven from the important elements of our architecture including VANET, Mobile Gateway, 4G LTE back hall access network. According to our architecture, we can consider three latency phases. In first phase, the latency relates to Wi-Fi access network. In VANET, vehicles send beacon frames each 20 millisecond. These beacon frames via IEEE 802.11p reach the Mobile gateway. Then, in second phase, gateway should analyze received packet and publish new SIP PUBLISH request, if it is necessary. In third phases, the packet should be transferred from mobile gateway to application server via LTE access network. In this case, latency relates to LTE access network and EPC processing. So, our communication latency in our architecture is:

$$\text{Latency}_{\text{communication}} = \text{Latency}_{\text{Wi-Fi}} + \text{Latency}_{\text{Mobile Gateway}} + \text{Latency}_{\text{LTE}} + \text{Latency}_{\text{EPC}}$$

In this architecture, we do not consider the mobile gateway and EPC latency because it is out of the scope of this thesis. Therefore the latency is:

$$\text{Latency}_{\text{communication}} = \text{Latency}_{\text{Wi-Fi}} + \text{Latency}_{\text{LTE}} \qquad (1)$$

where

$\text{Latency}_{\text{Wi-Fi}}$	The amount of time it takes from when beacon frame is passed down the requesting vehicle until it is placed on the mobile gateway.
$\text{Latency}_{\text{LTE}}$	The amount of time it takes from when SIP Publish request is passed down the mobile gateway until it is placed on the eNode B.

In following 4.1.2 and 4.1.3 sections, we will explain how to calculate $d_{\text{Wi-Fi}}$ and d_{LTE} in our architecture, respectively. Finally, in 4.1.4, we present our mathematical model of proposed architecture to calculate the communication delay.

4.1.2 Latency Analysis via Wi-Fi

To calculate the Wi-Fi delay, we assume VANET beacon frames reach the mobile gateway in the vehicle.

Wi-Fi delay is the time period to deliver packet from the OBU or other users' devices to the mobile gateway. This time includes processing delay, queuing delay and transmission delay. The processing delay relates to packet processing by the routing layer. After processing, the packet is inserted into queue for transmission. After queue delay, the packet is moved to the head of queue and ready for transmission. Transmission delay is the time for MAC layer protocol to successfully transmit the packet to another hop. Therefore, the Wi-Fi delay can be express as below:

$$\text{Latency}_{\text{Wi-Fi}} = D_t \qquad (2)$$

where

D_t	Transmission Delay

The priority access to the wireless medium in 802.11 is controlled by use of the inter frame space (IFS). The IFS determines the minimal time that the station has to let pass after the end of the frame, before it may transmit the certain type of the frame. Also, in order to minimize the probability of the collision, the random back-off mechanism is used to randomize moments for each station trying to access the wireless medium. When the medium access is idle, the back-off counter is decremented and while the medium access is busy the back-off counter is frozen.

For 802.11 MAC protocol, transmission delay includes timer back-off T_B, time freeze T_F and duration of successful transmission T_T. Therefore, the delay of 802.11 transmissions is sum of the timer back-off T_B, time freeze T_F and duration of successful transmission T_T.

$$D_t = T_B + T_F + T_T \qquad (3)$$

where

T_B	The duration of random time that station should differ the medium access in order to avoid the collision
T_F	The duration of time that the back-off counter freezes because of busy medium
T_T	The duration of successful transmission of data packet

In order to determine the transmission delay, first, we should calculate the collision probability in the exponential back-off mechanism in 802.11. In, Bianchi constructed a 2-

dimensional Markov chain model to describe the exponential back-off mechanism of 802.11. Then, Carvalho and Garcia-Luna-Aceves in applied Taylor series on Bianchi's result[29]. Therefore, the below expression is derived to calculate collision probability:

$$P = \frac{2w_{\min.}2K}{(W_{\min+1})^2 + 2W_{min}.2K} \qquad (4)$$

where

W_{min}	Minimum contention window size. W_{min}=32
2k	Number of contenders within the transmission rang

In equation (4), the collision probability is calculated. The number of maximum retransmission in 802.11 is limited to 7. So, according to [30] the expected number of retransmission upon successful packet delivery is:

$$E[s] = \sum_{s=1}^{7} sp^{s-1}(1-p) = \frac{1-8p^7+7p^8}{1-p} \qquad (5)$$

where

S	Number of back-off stages
P	Collision Probability

Therefore, the expected duration of timer back-off T_B can be derived as below:

$$T_B = \begin{cases} \frac{W_{min}\eta}{2}.\left(2^{E[s]}-1\right) & E[s] \le m \\ \frac{\eta}{2}.\left(W_{max} - W_{min} + W_{max}.(E[s]-m)\right) & E[s] > m \end{cases} \qquad (6)$$

where

W_{min}	Minimum contention window size. W_{min}=32
W_{max}	Maximum contention window size. $W_{max} = 1024$
s	Number of back-off stages
m	Maximum number of back-off stages, $W_{max} = 2^m . W_{min}$
η	Back-off time slot length. $\eta = 20\mu s$
$E[s]$	Number of retransmission

If the channel is busy, the back-off timer freezes. The channel considered busy in two cases: Successful transmission from neighbours or in the case of the collision.

To calculate duration of back-off timer freeze, we first calculate the number of transmission involved in one collision. According to [30], the number of transmission in one collision is equal to $f(t)$:

$$f(t) = \binom{2k}{t} \tau^t . (1-\tau)^{2k-t} \quad (7)$$

where

2k	Number of contenders within the transmission range
τ	Transmission probability = $\frac{2}{W_{min}+1}$
$f(t)$	Number of transmission for t vehicles

According to [30];

$$T_F = 2k + (2k+1).\left(\frac{E[s]-1}{\sum_{t=2}^{2k} t.f(t)}\right).P \quad (8)$$

Here P is the time period for a packet transmission including SIFS, DIFS, Data and ACK.

The duration of successful transmission is the time period to transmit the data packet:

$$T_T = \mathrm{P} = \frac{S}{R} \tag{9}$$

where

S	Packet Size
R	Transmission Rate

From (3), (6), (8) and (9), the transmission delay is:

$$D_t = \frac{W_{min}.\eta}{2} \cdot \left(2^{E[s]} - 1\right) + 2k + (2k+1).\left(\frac{E[s]-1}{\sum_{t=2}^{2k} t.f(t)}\right).P + P \tag{10}$$

Based on (2), (3) and (10), the latency of Wi-Fi access is:

$$\text{Latency}_{\text{Wi-Fi}} = \frac{W_{min}.\eta}{2} \cdot \left(2^{E[s]} - 1\right) + 2k + (2k+1).\left(\frac{E[s]-1}{\sum_{t=2}^{2k} t.f(t)}\right).P + P \tag{11}$$

The constant values related to (11) are shown in table 4.1.

Table 4.1.Formula Parameters

W_{min}	32
η	$20\mu s$
2k	1
s	**7**
Frame size	500 Bytes
Transmission Rate	10 Mbps

Based on table 4.1, (4), (5) and (7), the calculated values are shown in table 4.2

Table 4.2.Calculated Parameters in Wi-Fi Delay Formula

W_{min}	$P = \frac{2w_{\min.}2K}{(W_{\min+1})^2 + 2W_{min}.2K}$	$E[s] = \sum_{s=1}^{7} sp^{s-1}(1-p)$	$P = \frac{S}{R}$	Lateny Wi-Fi (ms)
32	0.1052	1.1176	0.0009	9

4.1.3 Latency Analysis via LTE

International Telecommunication Union (ITU) defines the requirement metric for LTE latency, which is shown in table 4.3. Control plane latency is defined as the time required for the User Equipment (EU) to change its state from idle state to active state. User plane latency is defined as one-way transmission time of the packet from IP layer in UE/E-UTRAN to IP layer in the EUTRAN/UE node. The User plane latency would be focused in this work because it is relevant for the performance of many applications.

Table 4.3.IMT-A Latency Requirements

Plane	Max Latency (ms)
Control Plane	100
User Plane	10

There are four main components that are involved in the latency calculation of LTE. These components are:

1. UE processing time
2. Transmission Time Interval (TTI) time
3. Hybrid Automatic Repeat Request (HARQ) retransmission
4. e Node B processing time

In figure 4.1, we can see the LTE user-plane latency calculation model in both TDD (Time Division Duplex) and FDD (Frequency Division Duplex) configuration.

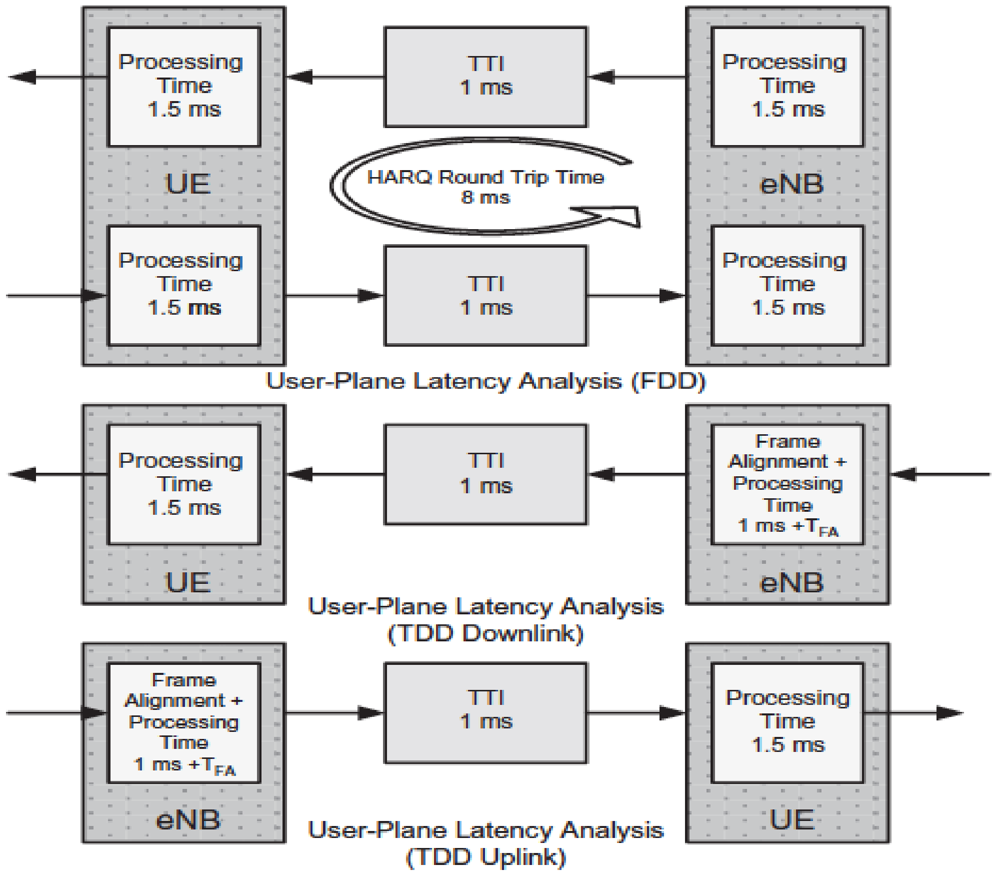

Figure 4.1. LTE user plane latency calculation model

As we said before, the LTE user-plane one-way access latency includes fixed node-processing delays including radio frame alignment and 1ms TTI duration. Using the latency calculation model shown in figure 4.1 and considering Hybrid Automatic Repeat Request (HARQ) process in FDD LTE configuration derive the following equations:

$$T_{USER\_PLANE\_FDD} = T_{UE} + TTI + T_{eNodeB} + N_{HARQ}p' \qquad (11)$$

where

T_{UE}	UE processing time = 1.5ms
TTI	TTI duration Time (Fixed) = 1ms
T_{eNodeB}	E Node B processing time = 1.5ms

N_{HARQ} Number of HARQ in FDD = 8

p' p' is the probability of HARQ retransmission

so

$$T_{USER\_PLANE\_FDD} = 4 + 8p' \quad (12)$$

As we can see in figure 4.2,with FDD configuration of LTE by increasing the probability of retransmission, the total delay increases.

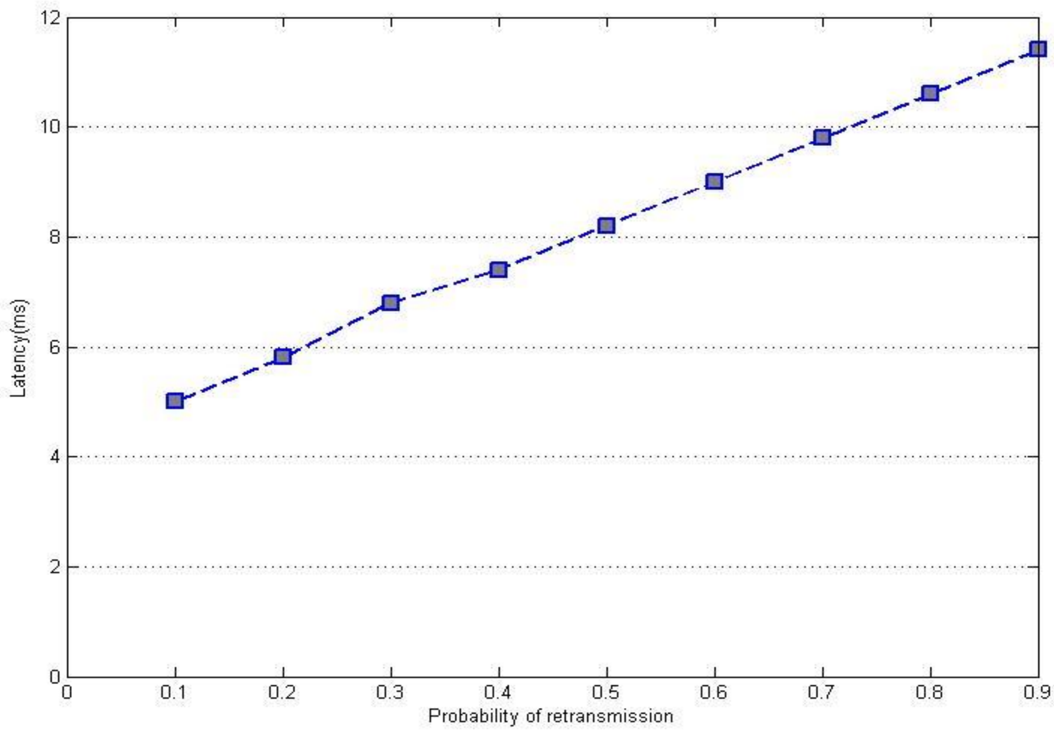

Figure 4.2. The impact of the probability on latency (LTE FDD configuration

With FDD LTE configuration, user-plane one-way access latency consists of fixed node-processing delays, which include radio frame alignment and one millisecond Transmission Time Interval (TTI) duration. Using the latency calculation model shown in Figure 4.1, and assuming that the number of HARQ processes is 8 for the FDD LTE configuration mode, the one-way latency is given as $T_{USER\_PLANE\_FDD} = 4 + 8p'$ where the p' is the probability of HARQ retransmission. If $p' = 0$ the minimum latency of $T_{USER\_PLANE\_FDD}$ = 4 milliseconds. However, the more realistic value of $T_{USER\_PLANE\_FDD}$ = 4.8 ms when the $p' = 0.1$. By increase of p' the amount of $T_{USER\_PLANE\_FDD}$ increases. In the worst case when p' is 0.9, $T_{USER\_PLANE\_FDD}$ reaches to pick amount almost 10.5 milliseconds.

While for TDD, the latency is:

$$T_{USER\_PLANE\_TDD} = T_{UE} + T_{eNodeB} + \ T_{FA} + TTI + p"T_{RTT} \quad (13)$$

where

T_{FA}	The radio frame alignment time (depends on various configuration of TDD frame structure)=2.5 milliseconds
TTI	TTI duration Time (Fixed)= 1 milliseconds
T_{RTT}	Average HARQ round-trip time = 10 milliseconds
$p"$	The error probability of the first HARQ transmission
T_{UE}	UE processing time= 1.5 milliseconds
T_{eNodeB}	eNodeB processing time = 1.5 milliseconds

so

$$T_{USER\_PLANE\_TDD} = 6 + 10p" \quad (14)$$

In figure 4.3, we can see that the increase of the retransmission probability results in the increase of the delay.

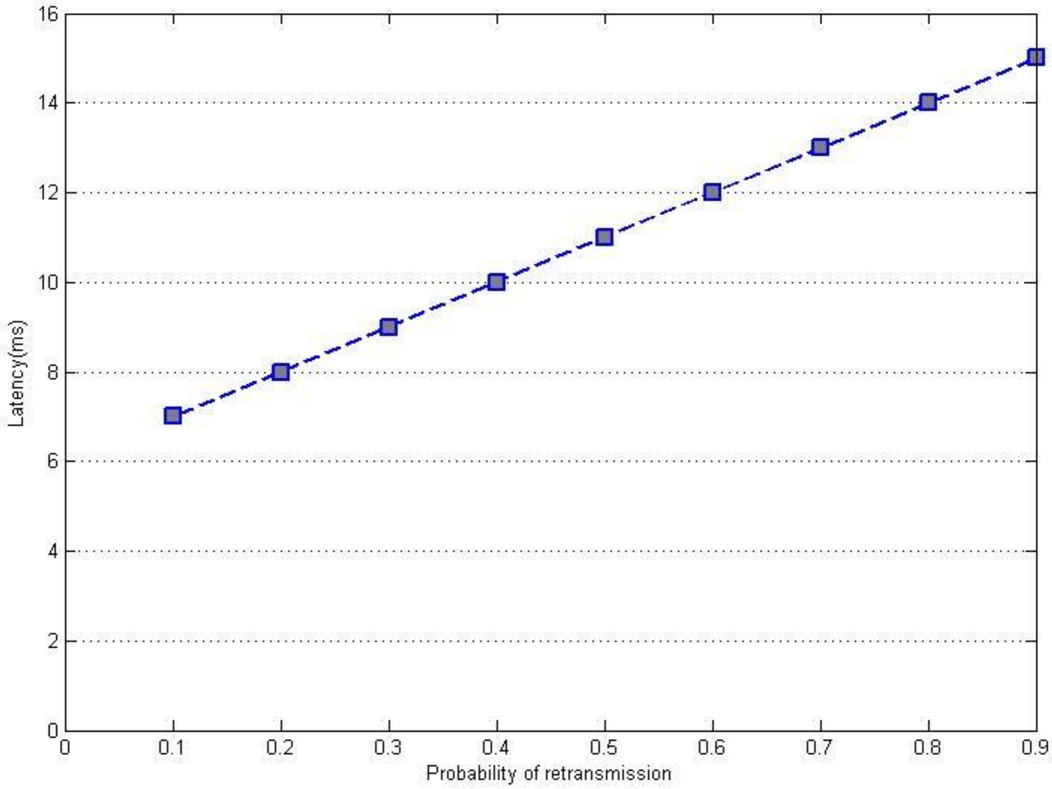

Figure 4.3. The impact of the probability on latency (LTE TDD configuration)

With TDD LTE configuration, user-plane one-way access latency consists of fixed node-processing delays, which include radio frame alignment and one millisecond Transmission Time Interval (TTI) duration. Using the latency calculation model shown in Figure 4.1, and assuming that the average HARQ round trip time is 10 milliseconds for the TDD LTE configuration mode, the one-way latency is given as $T_{USER\_PLANE\_TDD} = 6 + 10p''$ where the p'' is the probability of HARQ retransmission. If $p'' = 0$ the minimum latency of $T_{USER\_PLANE\_TDD} = 6$ milliseconds. However, the more realistic value of $T_{USER\_PLANE\_TDD} = 6.8$ ms when the $p'' = 0.1$. By increasing of p'' the amount of $T_{USER\_PLANE\_TDD}$ increases. In the worst case when p'' is 0.9, $T_{USER\_PLANE\_TDD}$ reaches to pick amount almost 15 milliseconds.

4.1.4 Total Communication delay

As we mentioned before in (1), the communication delay of our architecture is the sum of Wi-Fi and LTE delay.

$$\text{Latency}_{\text{communication}} = \text{Latency}_{\text{Wi-Fi}} + \text{Latency}_{\text{LTE}}$$

Also, LTE uses both FDD and TDD configuration. Therefore, our total delay depends on LTE configuration. For FDD configuration, the delay is:

$$\text{Latency}_{\text{communication}} = T_{USER\_PLANE\_FDD} + \text{Latency}_{\text{Wi-Fi}} \tag{15}$$

According to (10) and (12), $T_{USER\_PLANE\_FDD}$ is:

$$T_{USER\_PLANE\_FDD} = 4 + 8p'$$

and the latency of Wi-Fi is:

$$\text{Latency}_{\text{Wi-Fi}} = \frac{W_{min}.\eta}{2} \cdot \left(2^{E[s]} - 1\right) + 2k + (2k+1).\left(\frac{E[s]-1}{\sum_{t=2}^{2k} t.f(t)}\right).P + P$$

So, the total latency of our communication in LTE FDD configuration mode is the sum of the latency of LTE and Wi-Fi access mode:

$$\text{Latency}_{\text{Communication}} = \frac{W_{min}.\eta}{2} \cdot \left(2^{E[s]} - 1\right) + 2k + (2k+1).\left(\frac{E[s]-1}{\sum_{t=2}^{2k} t.f(t)}\right).P + P + 4 + 8p' \tag{16}$$

Figure 4.4 shows the total communication delay of our architecture in LTE FDD configuration.

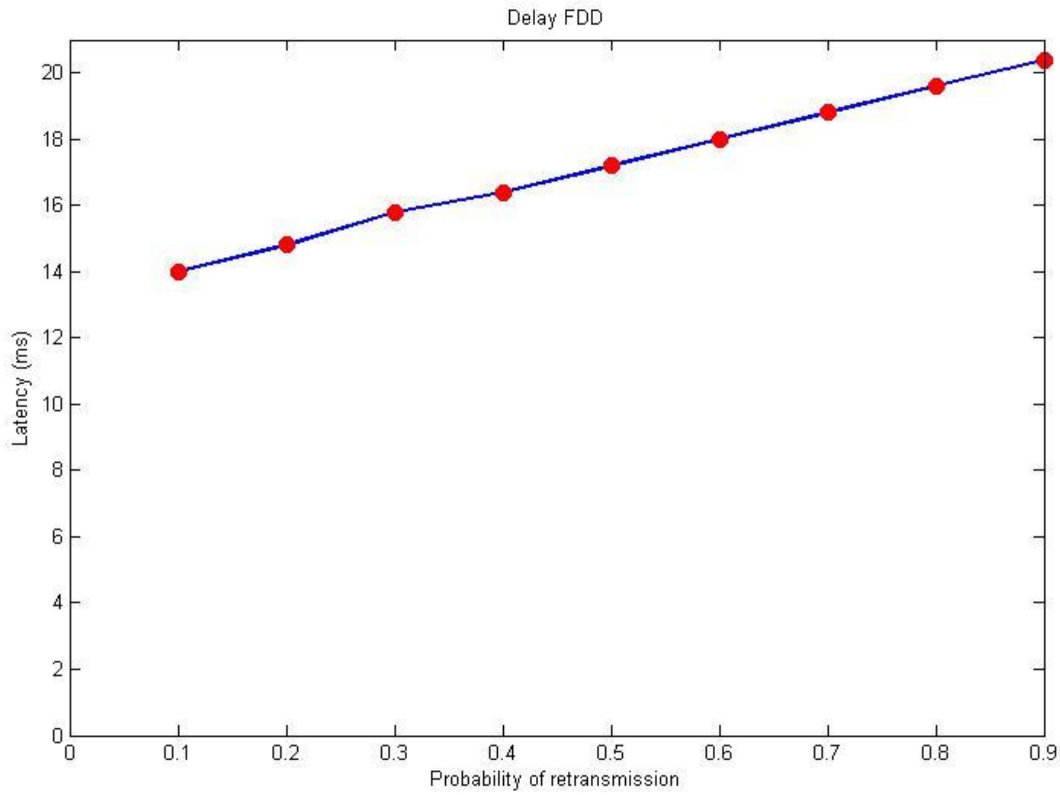

Figure 4.4. The impact of the probability on latency (LTE FDD configuration)

Figure 4.4 shows the total communication delay of our architecture in LTE FDD configuration. In section 4.2.1, we calculate the amount of Wi-Fi delay access network that is around 9 milliseconds. Also, we explain that the delay of LTE FDD configuration with the realist probability of retransmission is 4.8 milliseconds. Therefore, the total delay of our architecture in FDD LTE configuration is almost 14 milliseconds in the best situation. By increase of the retransmission probability in LTE FDD configuration the amount of $T_{USER\_PLANE\_FDD}$ increases, so the total delay goes up. In the worst case when p' is 0.9, the total communication delay of our architecture reaches to pick amount almost 20 milliseconds.

In TDD configuration of LTE, the total delay is:

$$\text{Latency}_{\text{communication}} = T_{USER\_PLANE\_TDD} + \text{Latency}_{\text{Wi-Fi}} \quad (17)$$

According to (10) and (13) we have:

Latency $_{\text{communication}} = \frac{W_{min} \cdot \eta}{2} \cdot \left(2^{E[s]} - 1\right) + 2k + (2k+1). \left(\frac{E[s]-1}{\sum_{t=2}^{2k} t.f(t)}\right). P + 6 + 10p"$ (18)

Figure 4.5 shows the total communication delay of our architecture in LTE TDD configuration.

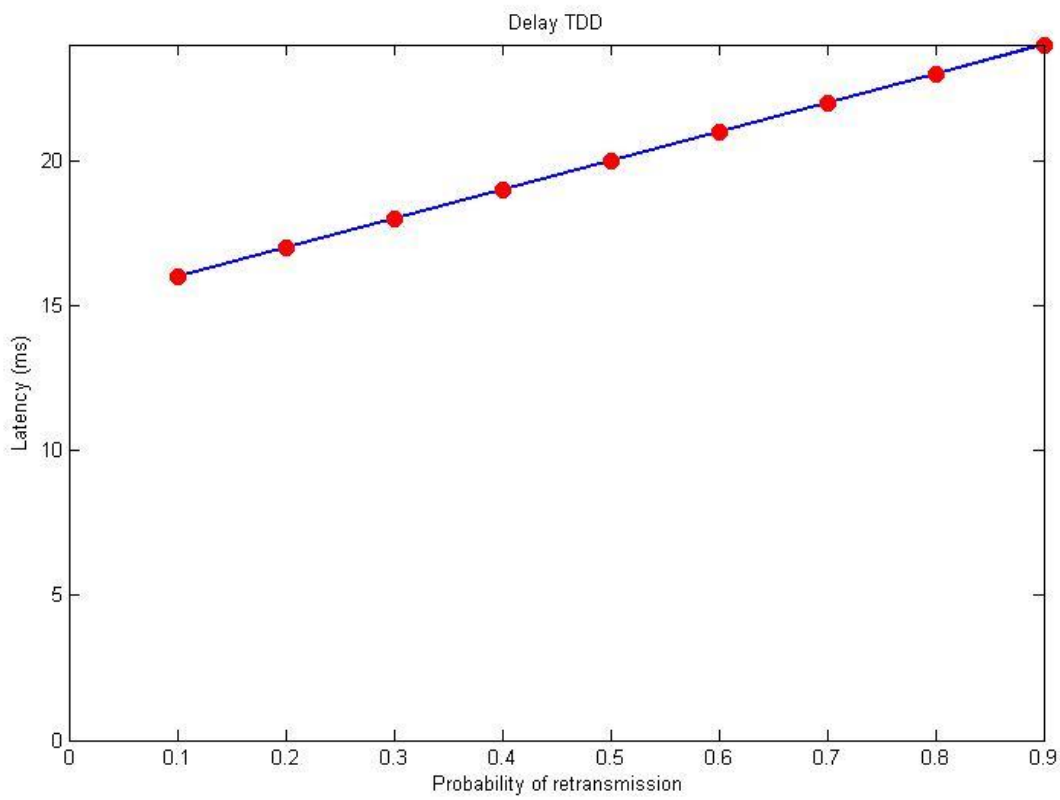

Figure 4.5. The impact of the probability on latency (LTE TDD configuration)

Figure 4.5 shows the total communication delay of our architecture in LTE TDD configuration. In section 4.2.1, we calculate the amount of Wi-Fi delay access network that is around 15 milliseconds. Also, we explain that the delay of LTE TDD configuration with the realist probability of retransmission is 6.8 milliseconds. Therefore, the total delay of our architecture in TDD LTE configuration is almost 17 milliseconds. By increase of the retransmission probability in LTE TDD configuration the amount of $T_{USER\_PLANE\_TDD}$ increases, so the total delay goes up. In the worst case when the probability of retransmission in LTE TDD configuration is 0.9, the total communication delay of our architecture reaches to pick amount at almost 25 milliseconds.

Based on fig 4.4 and fig 4.5, the FDD LTE configuration has less latency because LTE TDD configuration deploys frame alignment time, therefore the amount of total delay is more in TDD configuration.

4.2 Validation

In order to validate our architecture, firstly we will compare our proposal architecture with the other architecture that integrates VANET and IMS and were described in our state of the art. Secondly, we will prove our architecture through a simulation.

4.2.1 Architecture comparison

In the sate of the art, we consider different integration of VANET and IMS. Now, in this part we want to compare our work with the others from the latency perspective. The proposals that have been chosen for the comparison are IMS platform for VANET from [21], the secure and QoS-aware SIP handover for VOIP in VANET proposed from [31] and 3G VANET integration in [32].

Table 4.4 depicts the comparison among proposed architecture. In this table, we can see that which feature is supported or not supported in proposed architectures.

Table 4.4: Comparison among proposed architecture for Integration VANET and IMS

✖ :This feature is Available in architecture, ---: This feature is not Available in architecture

Architecture Features	Cloud Based IMS	IMS Platform for VANET	Secure & QoS SIP Handover	3G VANET Integration
Mobile Gateway	✖	---	---	✖
MIH	✖	---	---	---
4G (eNode B)	✖	---	---	---
IMS	✖	✖	---	✖
RSU	---	✖	✖	---

UMTS	---	---	---	✖

In IMS platform for VANET [21], the author presents a platform for deployment of vehicular services based on IMS and advanced capabilities. This work is based on enriched enablers over IMS Core Network. Enablers provide powerful presence functionalities to support instance messaging. In this scenario, vehicles equipped with OBU communicate to TCC center with Instant messaging system via IMS to inform the center about their situation. The vehicles communicate with servers via RSU. Therefore, RSUs are responsible to keep track the communication and handle the SIP session. In the case of poor network signal, it is possible to lost the communication because in this architecture the MIH is not considered. On the other hand, by using traditional IMS architecture, when there are a lot of demands for using the IMS services, the IMS server will be failed and cannot process the request. The RSU has the important role in this architecture. In that scenario, the authors perform 1000 tests for both Wi-Fi and UMTS technologies. According to the result of that scenario, the average latency over Wi-Fi for all the tests carried out is 129.06 milliseconds, and 525.48 milliseconds over UMTS. This amount of delay is more than that of we calculate in our scenario. More over at that scenario, VANET communicates via RSU and infrastructure with IMS Servers. This causes to increase the number of the handovers and interruptions during the SIP session.

In secure & QoS SIP Handover [31], the proposed architecture uses the SIP servers instead of the IMS infrastructure. In this architecture the RSUs handle the handover by communicating with each other. Each RSU sends the related information about security and QoS of established communication to the next candidate RSU. In fact, in this proposed architecture the RSU acts like the gateway. The author proves that the mean of the handover increases by passing the time. In this proposed architecture, the amount of delay is more than that of we calculated in our architecture. Furthermore, because of non-centralized infrastructure for controlling the QoS and security issues and frequently interruption due to handover, the performance of this proposed architecture is not acceptable.

In 3G VANET Integration[32], the author creates dynamic cluster depending on speed and direction of each vehicle in VANET. Each cluster has the head candidate equipped with mobile gateway. The ordinary vehicles that do not have mobile gateway communicate with head candidate of existed cluster. The head candidate of the cluster communicates with IMS infrastructure while using UMTS as access network. As we know, the UMTS cannot communicate directly with Internet infrastructure because the RNC should control all the received signals and after that GPRS generates IP packets and acts as the gateway. The delay of this proposed architecture is more than that of we calculated in this work.

Moreover, in all above-mentioned proposed architecture, the scalability, reliability and resource pooling are not considered. These features are supported in our architecture because of cloud Based architecture of the IMS. By using the MIH infrastructure in our architecture, the mobility and access network changed are abstracted from applications. Also, by using SIP Publish messages we can control the applications quality. So, we can guarantee the QoS for highly mobile nodes in VANET. The 4G backhaul access network also can improve the architecture because of high speed of EPC and LTE-advanced.

4.2.2 Simulation and results

In this section we evaluate the latency of the proposed architecture via extensive simulation. We simulate our solution on Network Simulator 2 (NS-2).

To simulate our proposed architecture, we configure the network components such as topography, queues, wireless channel, routing protocols, etc. Also, as we know in VANET each node will randomly choose a location to move towards with selective velocity. To simulate the VANET mobility in our simulation, we use two mobility models including Freeway Mobility model and Urban Mobility model. In Urban Mobility Model, we create traffic by using Simulation of Urban Mobility (SUMO) with Manhattan Mobility Model. Moreover, in Freeway Mobility Model, we create 50,100,120,150 and 200 nodes in NS-2 with 6 lanes highway (three lanes in each direction). In different mobility model for highway and urban model, we create the traffic from nodes to application server of Cloud based IMS. In our scenarios (highway and urban), we put one e Node B that communicates directly with Server. All the nodes communicate with this e Node B to send request and receive services from server. We examine our proposed architecture 10 times with Urban Mobility model and Freeway mobility model to measure and compare latency in different scenario. In table 4.5, we can see the simulation parameters in highway.

Table 4.5: Simulation parameters In Freeway Scenario

Parameters	Value
Total road length	2400(m)
Number of lanes	6(3 in each direction)
Number of vehicles	50,80,100,120,156,200
Mac-type	802.11p,LTE-advance
LTE bandwidth	20 Mhz -100 Mhz
802.11p bandwidth	10 Mhz
Vehicle speeds	50-120 (Km/h)
Simulation time	120(s)
Simulation runs	10

In table 4.6, we can see the simulation parameters in urban area.

Table 4.6: Simulation parameters In Urban Scenario

Parameters	Value
Total road length	600 m × 700 m
Number of vehicles	50,80,100,120,156,200
Mac-type	802.11p,LTE-advance
LTE bandwidth	20 Mhz -100 Mhz
802.11p bandwidth	10 Mhz

Vehicle speeds	0-50(Km/h)
Simulation time	120(s)
Simulation runs	10

Delay in urban scenario

Fig 4.6 shows the latency in urban area. We simulate 10 times the urban scenario with 50,80,100,120, 156 and 200 vehicles. We analyze the results of our simulation with Latency.awk to calculate the average latency in urban area. In fig 4.6, we can see that when the number of vehicles increases from 50 to 200, the rate of latency increases slightly from around 15ms to about 23ms. By increasing the number of vehicles, the number of packet conflicts rises. Therefore, the amount of latency increases. However, due to using 4G and LTE access network, the delay time increases significantly slightly because the bandwidth and transmission rate are optimized in LTE-advance access network.

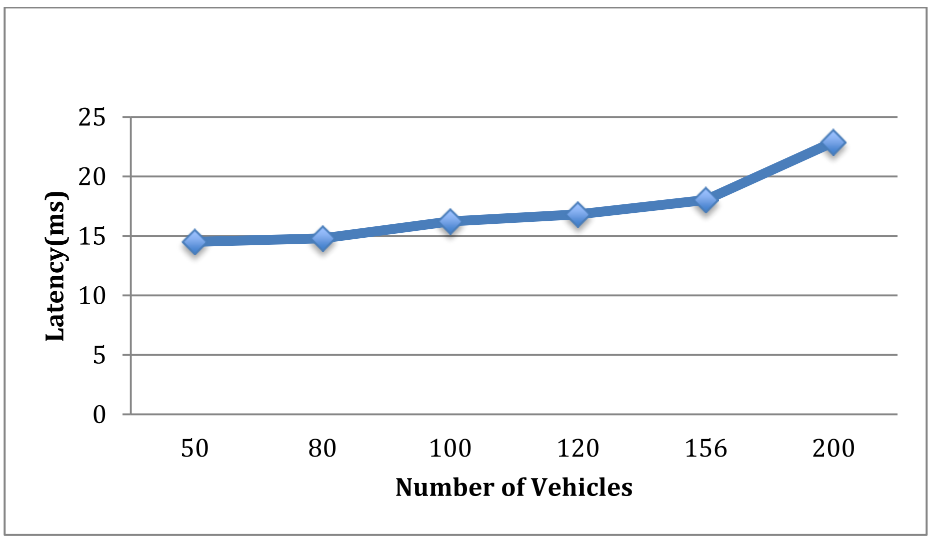

Figure 4.6. Latency in Urban Model

The amount of latency obtained by simulation with NS-2 in urban area is almost equal to the mount of latency that we calculated via mathematical model.

Delay in Freeway Scenario

In order to obtain the amount of latency in real area, we simulate Freeway scenario with NS-2 simulation. Fig 4.7 shows the amount of communication delay in our architecture. Like the urban area simulation, we put one e Node B in highway that communicates with application server in Cloud based IMS directly. In this simulation, we examine our scenario 10 times with 50,80,100,120,156 and 200 vehicles. The fig 4.7 illustrates that when the number of vehicles increases from 50 to 200, the amount of latency increases from about 14ms to almost 16ms. Compare to urban area, the amount of latency in Freeway model is lower. In freeway area vehicles move with high velocity from one e node B to another one, therefore the density of vehicles decline. When the density of vehicles is lower, the number of packet conflicts decreases so the latency improves.

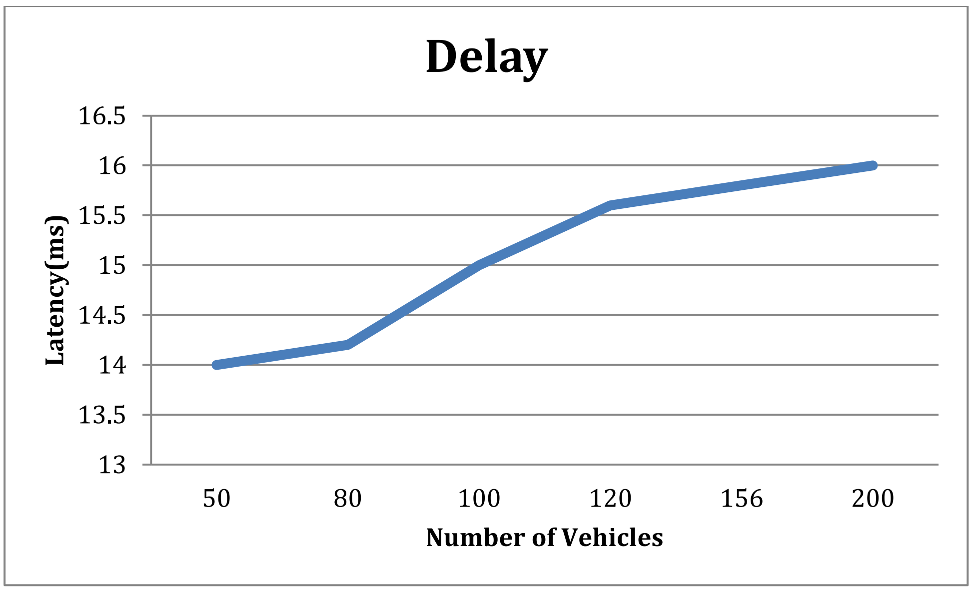

Figure 4.7.Latency in Freeway model

CONCLUSION

Our thesis proposes and validates Cloud Based IMS architecture for integrating VANET, IMS and Cloud Computing. The objective is to provide VANETs with multimedia service through Cloud based IMS. For this purpose, a mobile gateway is used as a middleware with appropriate features. In this section, we present a summary of the proposal and its results. They are followed by he limitations of this work, based on some assumptions. Finally, we announce the future works that could be done in this research area.

5.1 Summary of the work

Recently, VANETs have become an active area of research because of its major role to improve vehicle and road safety, traffic efficiency, and convenience as well as comfort to both drivers and passengers. VANETs support two kinds of applications: user applications and secure applications. User applications can provide road users with information, advertisements, and entertainment during their journey. Many of user applications in VANETs can be based on Internet connectivity. VANET is characterized by high mobility, high rate of topology changes and high variability in node density. Thus, providing all vehicular terminals with the Internet services raises major challenges. On the other hand, many users access new services provided by IMS. Therefore, providing the road user in VANETs with IMS services can open the new doors to VANETs. Traditional IMS architecture core network faces a set of problems such as centralized control, low efficiency and poor scalability of core equipment, compared with the IT environment using Cloud Computing. These observations are done in the literature review. Some models for integrating VANETs and IMS are also presented in literature review. There are some issues that are not covered in these models: 1) Middleware to control the communication between Vehicles and IMS application servers directly, 2) Appropriate architecture for IMS to improve the IMS services' functionality.

Therefore, the main goal of this research is to provide road users in VANETs with cloud based IMS services with acceptable QoS.

Our proposed architecture enables the dissemination of information from VANETs to IMS Application Servers in Cloud Computing. In order to propose and explain our architecture, we clarify two main requirements. The first requirement is to improve IMS functionality. For this purpose, we need to migrate IMS to Cloud Computing. New Cloud Based IMS architecture improves the quality of services because it inherits the Cloud Computing features including scalability, reliability and resource pooling. These features can improve the IMS function when there are a lot of demands to this IP-based network. For this purpose, the application servers and control server of IMS (C-CSCF, I-CSCF, S-CSCF) migrate to Cloud Computing. In Cloud Based IMS architecture, we consider the core network and Application servers of IMS as a new service in SaaS layer of Cloud Computing. The second requirement is a middleware devoted to translate the information from VANETs to Cloud Based IMS Application Servers and vice versa. This middleware should be able to communicate with VANETs and IMS. Therefore, it has two network interfaces: one to communicate with VANET and one to communicate with IMS.

Our proposed architecture is based on three layers: Device Layer, Communication Layer and Service Layer. Device Layer is the first layer in our architecture. This layer consists of vehicles equipped with mobile gateways (middleware). The second layer of our architecture is a Communication Layer. In Communication Layer that indicates the communication device, we choose the 4G back-hall access networks. The main motivation to choose 4G is its high speed of data transferring and capability of working with different network interfaces. In third layer named Service Layer, we have the IMS core network infrastructure, VANET Server and Application Servers. They are executed on virtual machines in Cloud Computing. These servers handle all the information received from vehicle and manage the mobility in application layer when multimedia session between vehicle and servers is established. In this scenario, the vehicle equipped with mobile gateways wants to establish the session with Application Server in Cloud based IMS. It is obvious that the road users have contract with service provider to utilize IMS services through Cloud Computing. The vehicles use SIP request to establish SIP session with Application Server in cloud based IMS. All the requests are passed through CSCFs servers to establish, manage and terminate the session. When vehicles gains IP address through DHCP servers and also discovers the IP address of its P-CSCF, it can begin registration with IMS core network. This IMS-Level registration can authenticate and authorize the road user to access the IMS services. Then, vehicle can establish the session with Cloud Based IMS Servers to use multimedia services. The OBU transmits periodically the state information of the vehicle to middleware through beacon messages. The state information of each node in VANET includes current location; speed, direction and QoS level such as available resource and bandwidth. The mobile gateway receives these beacon messages and compares them with the last previous one, which is received. If the content of Beacon messages changed (e.g. bandwidth), the gateway processes them to compose SIP PUBLISH messages. By receiving new state information of road user, the VANET server checks the subscription and finds the application server subscribing to presentity's information of that vehicle. The VANET Server uses the SIP SUSCRIBE message to inform the application server about the available bandwidth and the other state information of the vehicle. Therefore, the application server for example video server in Cloud Based IMS can Stream the video according to available bandwidth of the vehicle. This approach avoids exceeded packet lost, jitter and delay. The application server streams the video or the other services depend on to the available bandwidth the vehicle. In fact, in this scenario, the application server is able to respond to radio link changes during the session. Thus, real-time or streaming application continuity and QoS are preserved during handover.

Following the presentation of the architecture, a proof of concept of a real scenario is implemented in order to evaluate the feasibility of the system. The latency of the proposed architecture is evaluated via extensive simulation. Network Simulator 2 (NS-2) is used for this purpose. It is well-known that in VANET, each node chooses randomly a location to move towards with selective velocity. To simulate the VANET mobility, we use two mobility models including Freeway Mobility model and Urban Mobility model. In Urban Mobility Model, we create traffic by using Simulation of Urban Mobility (SUMO) with Manhattan Mobility Model. Moreover, in Freeway Mobility Model, we create 50,100,120,150 and 200 nodes in NS-2 with 6 lanes highway (three lanes in each direction). In different mobility model for highway and urban model, we create the traffic from nodes to application server of Cloud based IMS. We examine our proposed architecture 10 times with Urban Mobility model and Freeway mobility model to measure and compare latency in different scenario. The results illustrate that when the number of vehicles increases from 50 to 200 in freeway scenario, the communication latency of our architecture increases from about 14ms to almost 16ms in freeway scenario. We observe that when the number of vehicles increases from 50 to 200 in urban scenario, the rate of latency increases slightly from around 15ms to about 23ms. These results show how data dissemination requirements are successfully fulfilled. Also, we prove these results with mathematical models.

5.2 Limitation of this work

The work that has been proposed presents several limitations that should be taken into consideration when using the proposal and when defining a future research path. Initially, the proposed architecture relies on mobile gateway. Each vehicle as a road user should be equipped with Mobile Gateway in order to receive IMS services. Unfortunately, Mobile Gateway can impose extra cost to our architecture. The road users should spend considerable amount of money to equip their vehicles with this equipment. Additionally, the presence of the appropriate network interfaces in order to convey information from VANET to Cloud Based IMS application Server is assumed. Therefore, when there is no gateway, the architecture cannot guarantee a successful delivery with delay constraints in cellular networks. Finally, in this architecture, we assumed that each device that receives a message has a way to send back a response about a successfully or unsuccessfully reception. If this functionality is missing in such device, the delivery cannot be guaranteed. The second limitation of this work is Beacon messages. In VANET, each vehicle sends the beacon messages every 30 milliseconds. It is possible that the situation and presentity information of the vehicle is changed between two consequent beacon messages. In this case, the Cloud Based IMS Application Servers cannot receive real presentity information of the car. As a consequence, it is possible that the road users tolerate service interruption. The periodic beacon messages can reduce the functionality of our architecture.

5.3 Future work

Based on the proof of concept here developed/evaluated and the presented limitations, some future works are proposed. One of the most important works that should be executed to improve the current work is to avoid extra cost of the middleware. Vehicular Cloud Computing (VCC) is one of the solutions. VCC is a new hybrid technology that has a remarkable impact on traffic management and road safety by instantly using vehicular resources, such as computing, storage and Internet for decision-making. The Cloud Computing paradigm has enabled the exploitation of excess computing power. The vast number of vehicles on streets and parking lots can be used for public services. Some vehicle owners may agree to rent excess on board resources. Similarly, the drivers stuck in traffic congestion will agree to donate their on board computing resources to the other drivers to disseminate advertisement, secure messages and entertainment. VCC is introduced to leverage the on board resources and middleware in participating cars. The

Vehicular cloud computing architecture relies on three layers: inside-vehicle, communication and cloud. We can create new service in Cloud Layer of VCC named Middleware as a Service. It allows drivers to obtain services using very minimal infrastructure. VCC as a solution can reduce the cost of our proposed architecture because it is not necessary for all the vehicles to have the mobile gateway.

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